MISTLETOE AND THE BRUSHTAILED POSSUM IN SILVER BEECH FOREST, SOUTH WESTLAND, NEW ZEALAND.

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Table of Contents

List of figures

List of Tables

Abstract

The distribution of mistletoe in South Westland silver beech forest was investigated. Stand structure and densities of *Peraxilla colensoi* (pirita) were assessed along six altitudinal transects. Host size and forest structure were both found to be important factors influencing density and distribution of mistletoe. Generally large beech trees were favoured as mistletoe hosts. There was also significant variation in mistletoe density between forest types

In a different study the leaf area removed by possums and insects from a population of mistletoe plants was quantified over a nine month period. Insects browsed all plants, and on average consumed around 4% of each mistletoe's leaf area. The overall consumption of mistletoe leaf area by possums was around 2%, but possum browse was not evenly spread over the population. Of the forty plants sampled, seven were attacked by possums with one plant being heavily browsed. By the end of the monitoring period the leaf area retained by possum browsed plants was significantly lower than that of unbrowsed plants. If individual mistletoes continue to be selectively browsed then defoliation and death of some mistletoe plants seems a likely outcome.

Possum diet was assessed by means of gut sample analysis and compared to estimates of food availability within silver beech forest. Possums utilised a wide range of food types but two or three species were dominant at any particular time of the year. Seral species such as wineberry, pohuehue, fuchsia, and lawyer were generally the most important foods. Mistletoe was not an important food item, contributing less than 1% of annual possum diet.

CHAPTER ONE

General Introduction

Chapter outline: In this chapter the New Zealand mistletoe flora and some basic information on mistletoe biology is outlined. Evidence that New Zealands mistletoes have declined and that this contraction is linked to the spread of the possum is reviewed. Objectives of the study are presented.

1.1 Mistletoe

Mistletoes are a polyphyletic group of shrubby angiosperms that largely parasitise the aerial stems of perennial plants although some root parasites also occur. They are distributed throughout the world but are most diverse in the tropics. There are 1400 species of mistletoe most of which belong to the *Loranthaceae* (950 species) and the *Viscaceae* (400 species), a few species occur in the *Eremolepidaceae, Myzodendraceae* and *Santalaceae* . The New Zealand mistletoe flora comprises three *Viscaeae* and six *Loranthaceae* species including *Peraxilla colensoi* (pirita) which forms the focus of this study.

Mistletoe biology

Little is known of the biology of *Peraxilla* or other New Zealand mistletoes. It is probable that the biological characteristics of *Peraxilla* are similar to those of other hemi-parasitic *Loranthaceae*. These plants have green leaves and thus produce organic food by photosynthesis, but are dependant on the host for water and nutrients. In order to achieve this, stem parasitic mistletoes have acquired specialized features. They have forsaken a conventional root system for one or more haustoria (woody intrusive organs that anchor the mistletoe

into the hosts vascular elements). Upon germination of a mistletoe seed the radicle (embryonic root) grows towards the host branch and forms, upon contact, a haustorial disk. A wedge of tissue from the radicular swelling subsequently penetrates the host bark to make contact with the underlying tissues, and develops into the primary haustorium. Through this haustorial connection mistletoe actively take up water and nutrients from host vascular tissues (Kuijt, 1969).

Seed dissemination is a potential problem for mistletoes. Seeds must be dispersed to the branches of suitable hosts, an unusual and precise requirement. The seeds of most mistletoes, including New Zealands species are surrounded by a viscous fleshy tissue (Ogle & Wilson, 1985). Once the ectocarp surrounding the fruit has been removed its tissue cements the seed to the substrate on which it lands or is deposited. But how are seeds transferred from parasite to host?. Some plants such as the dwarf mistletoes *Arceuthobium* have evolved explosive fruits which propel seeds through the air. However, the vast majority of mistletoes are dispersed by birds (Kuijt, 1969). Fruit-eating birds ingest the fleshy fruits as a source of carbohydrate and in turn may defaecate or regurgitate the semi digested seeds in a suitable site for infection (Reid, 1986). Bird pollination prevails within the *Loranthaceae.*, possibly because birds increase the chances of outcrossing by flying further than insects (Reid, 1986). Unfortunately little is known about pollinators or seed vectors of New Zealand mistletoes. Several mistletoe species (eg. *Peraxilla, Alepis* and *Trilipedea*) have brightly coloured flowers and it is possible these flowers serve as a visual attractant to avian pollinators. Tui have been observed feeding on *Peraxilla* flowers (D. Norton pers. comm.) and in South Westland kaka (*Nestor meridionalis*) are known to intensively feed on the nectar of pirita. Pirita fruit are also an autumn food source of birds such as the yellow head (*Mohoua ochrocephala*) and wood pigeon (*Hemiphaga*

novaeseelandiae) (O' Donnell & Dilks, 1986). The role of these or any other bird species in the reproductive biology our mistletoes unfortunately has not yet been established.

New Zealands mistletoe flora

New Zealands mistletoes are derived from elements of an ancient Gondwanian flora. All our species are endemic and esssentially primative, having undergone relatively little evolutionary change since the fragmentation of the super continent some 70 million years ago (Barlow, 1981).

The New Zealand mistletoe flora comprises six *Loranthaceae* and three *Viscaeae* species; the following descriptions of host species and mistletoe ranges are based on those in Poole and Adams (1990).

The *Loranthaceae* mistletoes are:

Peraxilla colensoi : New Zealands' largest mistletoe with plants measuring up to 3m across. It occurs in both the North and South Island from East Cape southwards, mostly in montane localities. The usual hosts are **Nothofagus menziesii* and occasionally *N. fusca.*

Peraxilla tetrapetala : Widely distributed in North and South Islands but is more frequently found in montane habitats. The usual hosts are *Quintinnia serrata* in the northern part of the North Island and *Nothofagus solandri* var. *cliffortioides* in its remaining range.

Alepis flavida : Found in the North and South Islands from the volcanic plateau southwards and again is most common in montane habitats. The

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* Nomenclature follows Allan (1961)

usual host is *Nothofagus solandri* var. *cliffortioides* but *N. fusca, N. solandri* and *N. truncata* are occasional hosts.

Ileostylus micranthus : Parasitic on a wide range of native and introduced trees and shrubs. Found in lowland areas from Kataia to Stewart Island and also on Norfolk Island.

Tupeia antartica : Parasitic on a range of native and introduced trees, although particularily common on *Carpodetus serratus* and *Pseudopanax arboreus*. It is also known to occasionally parasitise *Ileostylus*. Occurs in lowland and montane habitats from the Bay of Islands to Southland.

Trilepidea adamsii : Known previously from near Cambridge, Thames, Hunua, Waiheke Island, and Hunua. Not seen since 1954 - presumed extinct (Norton,1991).

New Zealands three *Viscaceae* mistletoes are all members of the genus *Korthalsella* (dwarf mistletoes).

The *Viscaceae* :

Korthalsella salicornioide : Usually parasitic on manuka (*Leptospermum*) and kanuka (*Kunzea*) in lowland and montane areas from North Cape to Stewart Island.

K. lindsayi : Parasitic on a range of trees and shrubs in lowland and montane areas from the East Coast to Southland.

K. clavata : Tufted plant parasitic on several trees and shrubs distributed in

montane habitats from the central North Island to Southland.

Peraxilla colensoi (pirita) forms the focus of this study. It is the most commonly occurring mistletoe species in South Westland's silver beech forest, the smaller leaved *P. tetrapetala* (pirirangi) is also present in this area but only at higher altitudes.

The decline of mistletoes

Earlier this century many botanists noted that mistletoe was a widespread and conspicuous feature of many of our forests. Townson (1907), for example, writing about the botany of the Westport District, made the following observations about mistletoes; with reference to the Mt Rochford area,

"I have seen trees fairly ablaze with the scarlet flowers of *Elytranthe tetrapetala* in the early summer" and at Fox River "*Elytranthe colensoi* showed in scarlet masses pendent from the limbs of *Fagus fusca*".

Today mistletoes are exceedingly uncommon in north Westland and Buller, with reliable records of perhaps less than 20 plants in recent years (Norton, 1993). Similar historical accounts of mistletoe abundance were made by Potts (1882) Laing and Blackwell (1906). There have been widespread reports of forests where mistletoe was once abundant today containing few or no mistletoe (Ogle & Wilson, 1985). It is generally accepted that in some areas our mistletoe flora has declined in the last 50-60 years and that one species (*Trilepidea adamsii*), the sole member of an endemic genus is now extinct (Given, 1981; Norton, 1991).

Anecdotal evidence has linked the decline of mistletoes with the expansion of the introduced Common Brushtailed Possum (*Trichosurus vulpecula* Kerr);

mistletoe populations have been observed to decline as possums have colonised an area (Ogle & Wilson, 1985; Brockie, 1992). In the only published quantitative study of possum impacts on mistletoe, Wilson (1984), found in Nelson that browsing possums, even at low colonising densities, rapidly depleted mistletoe populations.

Mistletoes are known to be palatable plants; in the northern hemisphere they are readily eaten by stock, and are even cut from trees to provide fodder (Gill & Hawksworth, 1961). In Australia a range of arboreal marsupials are known to feed on the foliage and fruit of mistletoes and possums are known to prefer mistletoe foliage to that of their host trees (Barlow & Wiens, 1977; Freeland & Winter, 1975).

It is likely that cryptic mimicry in Australian mistletoes has evolved as a response to marsupial browsing (Barlow & Wiens, 1977). Bannister (1989) has suggested that some New Zealand mistletoes also mimic their hosts. If this host resemblance does exist it has evolved in the absence of browsing mammals and is unlikely to provide an effective defense against the introduced possum.

1.2 Possums in New Zealands indigineous forests

Late last century the common brushtail possum was successful liberated in New Zealand to establish a fur industry (see Pracy 1962, for history of colonisation). The introduction of possums into a country previously without arboreal mammals has had a profound affect on our forest ecosystems (Green, 1984). The first signs that there were costs associated with possum colonisation appeared when land owners began complaining about damage to crops and tree plantings around 1910. Early investigations concluded that the damage done to forests and orchards was far outweighed by possums' value to the fur

trade. Debate continued as to the costs and benefits of possums, but by the 1940's there was increasing evidence of the detrimental effects possums were having on the health of indigineous forests. In 1947, after sixty years of political indecisiveness all legal protection was removed and the animals official status changed from a valued fur bearer to an introduced pest (Zotov, 1949).

Today, concerns about the impact of possums on mistletoe are heightened by observations of dramatic declines in several native plants species that have been induced by possums. Areas of extensive canopy defoliation and tree mortality attributed to possums have been described in detail in many New Zealand forests. In the podocarp-broadleaved forests of the southern North Island local elimination of palatable species such as five finger (*Pseudopanax arboreus*), tutu (*Coriaria arborea*), toro (*Myrsine salicina*) and fuchsia (*Fuchsia excorticata*) has been recorded by Fitzgerald (1976) and Cambell (1990). Others such as Coleman et al (1980) describe defoliation and deaths of a variety of canopy and sub canopy species in mixed hardwood forests on the slopes of Mount Bryan O'Lynn, Westland, and Pekelharing (1979) made observations of canopy defoliation coinciding with high possum densities in rata/kamahi forests in the Taramakau catchment. Although other factors such as even age stand senesence (Veblen and Stewart, 1982) are undoubtedly playing a role in forest change, the impact of the possum is now more clearly understood.

The selective nature of possum browsing heightens its potential impact on mistletoe. While the total number of food plants is large the bulk of possum diet in any one locality is concentrated on a relatively small number of species (Mason, 1958; Fitzgerald, 1976; Green, 1984). These regularly browsed species are often referred to as "preferred" or "palatable" and are at greatest risk of being browsed, at least locally, to extinction.

1.3 South Westland-a "mistletoe stronghold"

Although mistletoes are now uncommon in many areas, especially in the North Island and Northern South Island they are still common in some parts of the country, particularily in the south of the South Island and including South Westland. (Ogle & Wilson, 1985). It has been suggested that areas such as South Westland have retained large mistletoe populations because of historically low possum numbers. South Westland's forests are now under threat from invading and steadily growing possum populations (Rose, *et al.* 1990). Possums have not been considered a problem in beech (*Nothofagus*) forest because they rarely feed directly on beech trees themselves (Wardle,1984). However this rationale overlooks the potential loss of components of the beech ecosystems such as seral communities and mistletoe which are known to be important food sources for birds (O' Donnell & Dilks, 1986). In response to this threat the Department of Conservation has initiated ongoing possum control programs in parts of South Westland. Areas have been selected on the basis of the outstanding wildlife and botanical values at risk (James, 1990). The apparent sensitivity of mistletoe to possum impacts (Wilson, 1984) and its importance within these forest ecosystems (O'Donnell & Dilks, 1986; Rose, *et al.*, 1990) has prompted the Department to measure the performance of possum control operations by monitoring the condition of mistletoe plants. The use of mistletoe as an indicator of possum impact in beech forest, and the lack of basic ecological information on our mistletoe flora prompted this study of mistletoe and possums in South Westland.

1.4 General study aims

There has been considerable speculation as to the impacts of possums on mistletoe but no quantitative research on the mistletoe-possum relationship apart from Wilson's (1984) study. There is a comparable lack of information to answer basic ecological questions such as, how common are mistletoes naturally? and, what is there optimum habitat?.

This study has three main research aims:

1) Determine "natural patterns" of mistletoe abundance and investigate relationships between mistletoe distribution and environmental variables.

2) Quantify the amount of possum browse occurring on a sample of mistletoe plants over four quarters.

3) Analyse possum diet to determine the relative importance of mistletoe and other food species.

CHAPTER TWO

Study Area

Chapter outline: This chapter characterises the landforms, climate, vegetation and history of possum occupation of the study catchment. The physical characteristics of two study areas located within this catchment are then described and compared.

2.1 Location

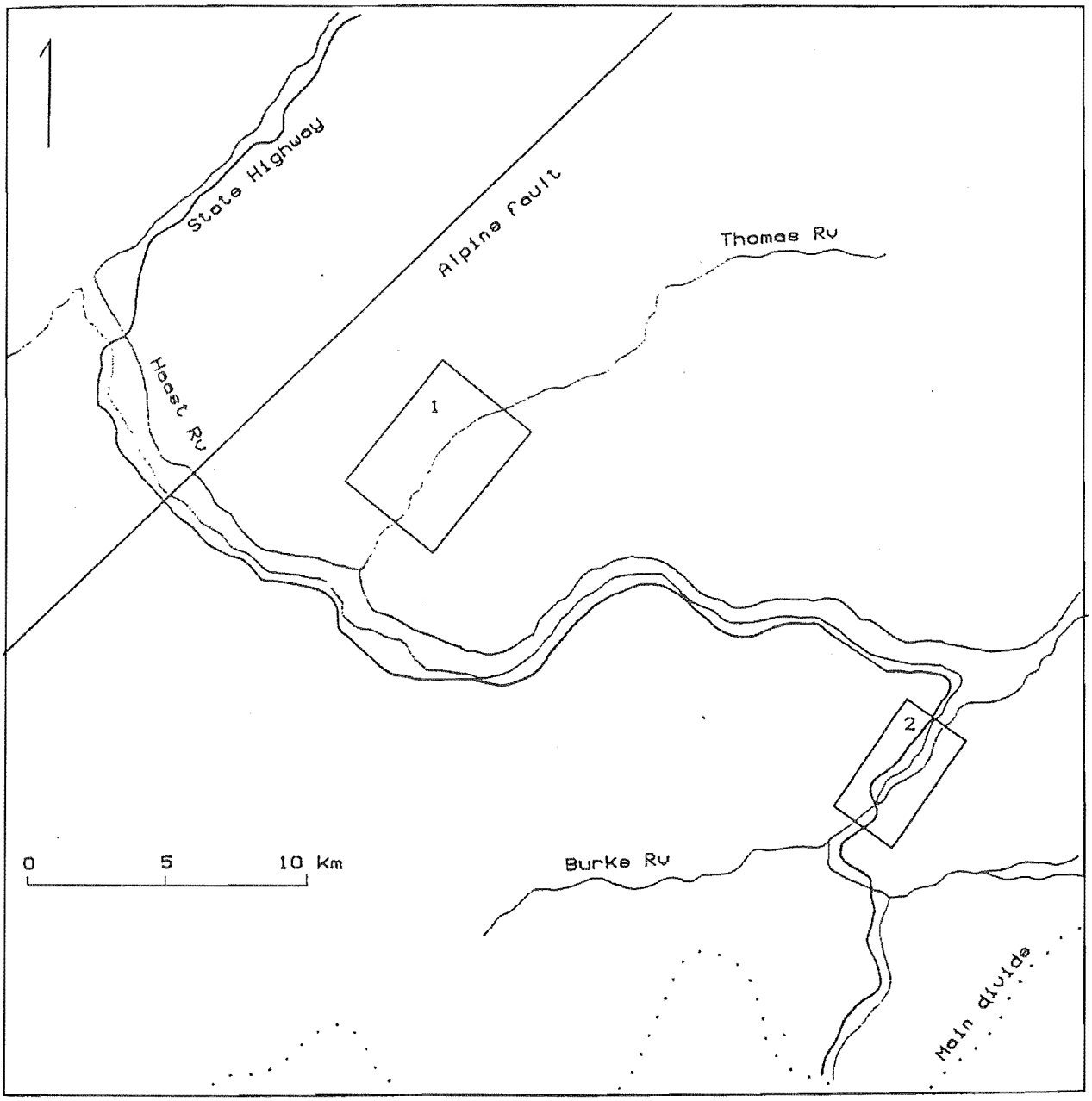
The study was undertaken at two sites within the Haast river catchment, South Westland, New Zealand (Figure 2.1).

2.2 Geology, landform and soils

The physical features of the Haast Valley are typical of the South Westland area, comprising steep narrow valleys in the upper reaches of the drainage giving way to extensive open river flats in the lower valleys.

The geology of the Haast catchment is dominated by the Alpine Fault which sharply differentiates the mountains of South Westland to the east, from the low forested coastal plains to the west. The geological history of the mountainous country east of the alpine fault is characterised to a large part by mountain building, earthquake activity, metamorphism and glaciation. The parent rock of the Haast drainage area is relatively uniform, consisting of quartzo-feldspathic schist of the Haast Schist Group of metamorphic rocks, except for deposits of gravel, silt, and sand on most valley floors (Bamford, *et al.*,1978).

Figure 2.1 Location of Study Areas within the Haast Catchment



1) Thomas Valley

2) Upper Haast

Soils consist predominantly of Upland and High Country Yellow-brown Earths and Podzols. In addition to these soils, valley floor alluvium is associated with Recent Soils of the Matukituki soil set. All of the podzolised soils are strongly leached and therefore of low nutrient status (Mark, 1977).

2.3 Climate

South Westland's weather patterns are predominantly the result of its mountainous topography and westerly situation. The combination of moist westerly air flows and orographic influences make it a region of consistently high rainfall (Hessel, 1982). The spatial distribution of rainfall is strongly dependent on altitude, less rain falling near the sea coast (around 3500 mm of mean annual precipitation is recorded at Haast township) while as much 10 000 mm may fall on the western flanks of the main divide (Bamford, *et al.*,1978). Rainfall is usually highest in spring and lowest in winter months (Hessel, 1982).

Despite South Westland's high rainfall, sunshine hours for all seasons except spring are similar on the South Islands west and east coasts. In general the mean temperature range in South Westland is smaller than elsewhere in New Zealand due to the modifying effects of the sea and lack of foehn winds. The mean temperature at Haast township (4 m above sea level.) is around 14° C in summer and 8° C in winter (Mark, 1977). The altitudinal lapse rate (temperature decrease with altitude) corresponds to about 6° C per 1000 m (Bamford, *et al.*,1978).

2.4 Vegetation

The most notable feature of the region is the dominance of silver beech (*Nothofagus menziesii*) sharply differentiating it botanically from the rata-kamahi (*Metrosideros umbellata-Weinmannia racemosa*) forests which are extensive north of the Paringa river (Wardle, 1980). Although silver beech is usually a dominant or co-dominant species, forest structure and associated species vary according to local climatic and

physiographical influences.

The broad vegetation descriptions which follow are based on those of Mark (1977) and are restricted to tall forest associations occurring within the Haast catchment.

Montane silver beech forest is the highest altitude tall forest association occuring from 350-400 m upwards to between 550 and 750 m. It is characterised by dense stands of silver beech which with scattered Hall's totara (*Podocarpus halli*) form a closed canopy. Kamahi (*Weinmannia racemosa*) and *Pseudopanax simplex* dominate the small tree layer and there is a well defined shrub layer in which *Coprosma* spp., *Myrsine divaricata* and horopito (*Pseudowintera colorata*) are common.

The beech forest below about 400 m is much richer in associated plants and classified as Silver Beech-Podocarp-Broadleaved mixed forest. Emergent podocarps are present but usually less abundant than silver beech, except below about 250 m where silver beech may be of equal or sometimes even of less importance than the podocarps. The small tree layer is dominated by kamahi. The understorey is diverse, common species including broadleaf (*Griselinia littoralis*), fuchsia (*Fuchsia excorticata*), pate (*schefflera digitata*), *Pseuodopanax edgerleyi*, kaikomako (*Pennantia corymbosa*), pigeonwood (*Hedycarya arborea*) and the tree ferns *Cyathea smithii* and *Dicksonia squarrosa* .

Locally, on ridge crests, southern rata (*Metrosideros umbellata*) may share equal importance with kamahi forming a short open forest, smaller stems of rimu (*Dacryduim cupressium*), Hall's totara silver beech and celery pine (*Phylocladus alpinus*) are present and bryophytes cover 80-90% of the forest floor.

On valley floors the soil parent material of unconsolidated alluvium together with a tendency towards frostiness, result in a vegetation pattern different from that of

neighbouring slopes.and silver beech dominates. This partly reflects cold air drainage and partly the ability of beech seedlings to rapidly colonise bare areas formed by fluvial erosion and deposition.

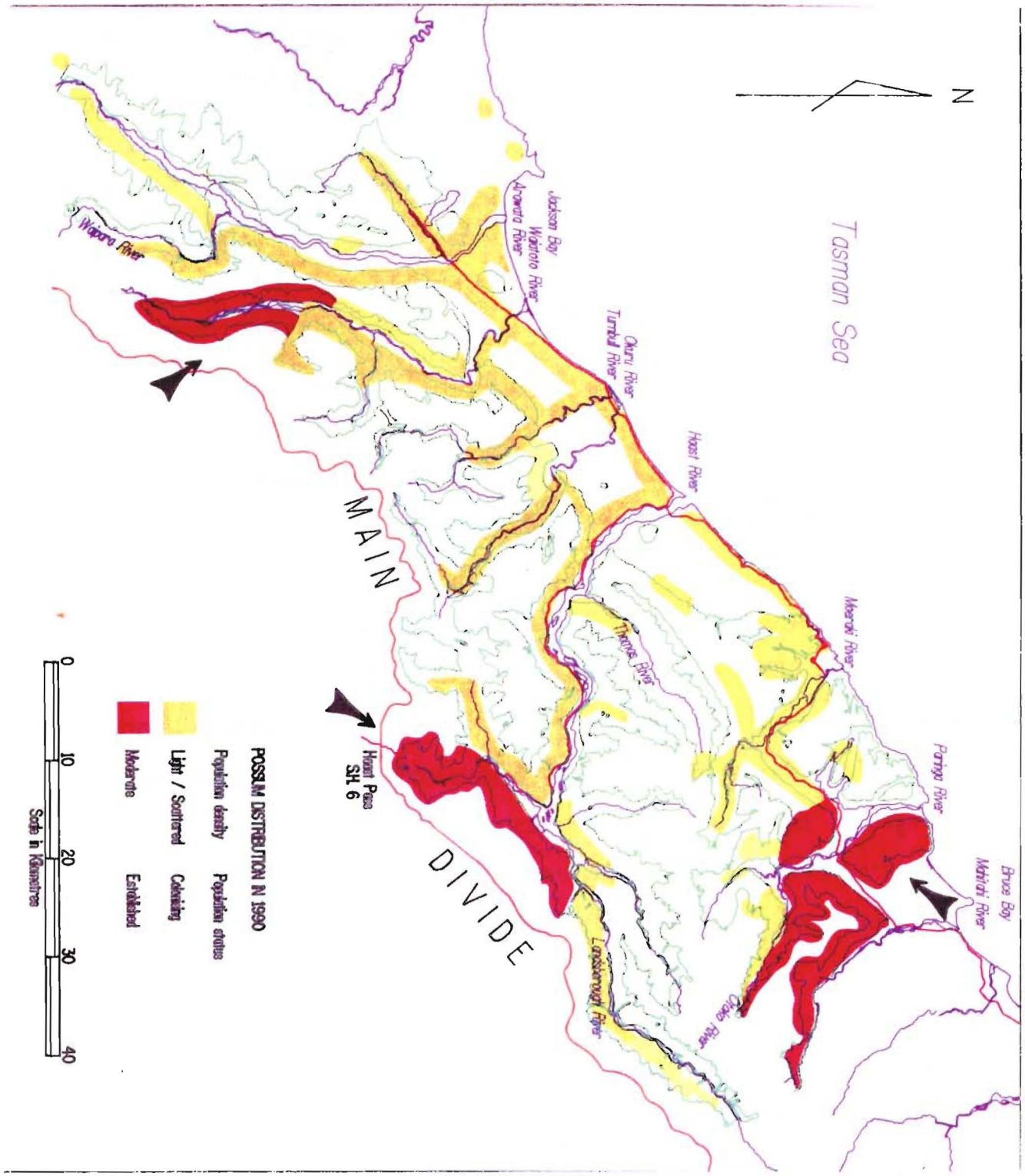
2.5 Possum colonisation of the Haast catchment

Present possum distributions, densities, and patterns of invasion in South Westland are shown in Figure 2.2. The build up and spread of possums into catchments south of the Paringa river has been relatively slow compared to patterns observed in Central Westland. Although possums have been present in parts of South Westland for over 50 years, densities are still considerably less than areas in Central Westland colonised more recently.(Rose *et al.* 1990; Pekelhering, 1979). The principal factors responsible for the contrasting patterns of population buildup are thought to relate to the poorer food quality of silver beech forest compared to rata-kamahi associations, and the geographical isolation of many southern catchments.

The first possums to colonise the Haast Valley probably migrated over Haast Pass from the Makarora catchment, where 20 possums were liberated in 1914. By 1950 they had spread past Pleasant Flat up the eastern bank of the Landsborough Valley and down the Haast Valley highway (Rose *et al.* 1990). Currently the river terraces around Pleasant Flat support a well established possum population but one still at pre-peak densities (Rose *et al.* 1990). Possum access to the north bank of the Haast river has been restricted by the absence of bridges and roads. Largely as a result of this isolation, possums are not thought to have reached the Thomas Valley until the last 10-15 years (James, 1990) and current densities are still at or near zero (G. McDonald pers. comm). Possums which have colonised the Thomas Valley have probably invaded from the Moeraki Valley to the north, which has been slowly colonised along the Lake Paringa/Windbag road corridor (Buglass, 1991). Possum densities in the Moeraki Valley are however known to be low

(Farrell & Mead, 1990; Buglass,1991) and are currently being reduced by Department of Conservation possum control operations.

Figure 2.2 Distribution and inferred status of South Westland possum populations. (source Rose et. al.,1990)



2.6 Location of study areas (Figure 2.1)

1) Thomas River Valley: This river flows into the Haast River 15 km from the coast. To the west this valley is flanked by the rolling Mataketake range and to the east by the Thomas range. Field work was under taken in the mid reaches of the valley, Latitude 43 54' S, Longitude 169 12' E

2) Upper Haast Valley: Alluvial terraces in the Haast Valley some 35 km inland from the Haast-Thomas confluence, Latitude 44 01' S, Longitude 169 23' E.

The two study sites are approximately 25 km apart.

2.7 Description of study areas

Topics of research and physical characteristics of each area are described in Tables 2.1 and 2.2.

The Thomas Valley (study area 1) lacks the extensive river flats of the Haast Valley. Within the Thomas Valley study site recent soils of alluvial terraces are confined to the valleys narrow floor. Under its forested slopes Haast Steepland soils predominate. These soils are strongly leached and have a low nutrient status. Locally, impeded soil drainage is demonstrated by changes in vegetation composition (Bamford *et al.*, 1978). Forest patterns in the Thomas Valley study site largely mirror those described in the preceding section (see 2.4 Vegetation).

The Upper Haast river terraces (study area 2) have been formed by recent depositions of unconsolidated alluvium. These depositions of gravel and silt form the parent material for Recent Soils of the Matukituki soil set (Mark, 1977). Large silver beech trees form a tall forest canopy over the surfaces apart for some small areas cleared for cattle grazing. Within the silver beech canopy mistletoe are

common. The most important components of the sub-canopy and shrub tiers are *Coprosma* and *Pseudopanx* spp, rohutu (*Neomyrtus pedunculata*) and horopito. Seral species (eg. fuchsia, wineberry, and pate) are abundant around forest margins and in canopy gaps. Shield fern (*Polystichum vestitum*) and *Blechnum* ferns are common on the forest floor.

Table 2.1 Research topics and study areas.

site 1) Thomas River Valley:	mistletoe distribution and density patterns
site 2) Upper Haast:	possum - mistletoe interactions

Table 2.2 Physical description of study areas:

site 1) Thomas River Valley:

site 2) Upper Haast:

	Altitude	Rainfall	Physiography	Forest types	Possum density
site1	150-700m.	5000 mm.	terrace, ridge gully, and face surfaces.	silver beech, beech-podocarp, and beech-broadleaved.	very low/zero.
site2	150m.	4500 mm.	alluvial terrace.	silver beech.	established, pre peak.

CHAPTER THREE

The distribution of *Peraxilla colensoi* in Silver Beech forest

Chapter outline: This chapter looks at the distribution of pirita in a silver beech forest virtually unmodified by possums. A background is given to the types of factors which may influence the distribution patterns of mistletoe. Methodologies used in field work and data analysis are outlined. Results showing patterns of mistletoe density and distribution are presented, and likely relationships of these patterns to environmental variations are discussed.

3.1 Introduction

Little research has been carried out in New Zealand on the ecology of our mistletoe flora. This deficiency in knowledge is in marked contrast to the number of studies of host-parasite relationships, mistletoe distribution and dispersal patterns in Australia and the Northern Hemisphere (for examples see Hawksworth, 1961; Reid & Yan, in press). What knowledge there is of New Zealand mistletoes consists mainly of generalised geographical patterns and anecdotal accounts. It is known that pirita occurs in lowland and montane forest from the Central North Island to Foveaux Strait. What the distribution patterns of pirita are within these forests and to what environmental variables they are related is largely unknown.

An understanding of natural factors involved in limiting mistletoe abundance is especially relevant given present concerns about the impacts of possums on mistletoe populations throughout the country.

A study of plant synecology usually involves among other things the collection of information on the abundance patterns of plant species. Plant distributions can then be compared to gradients or variations, in the environment such as altitude soil fertility, drainage, etc. Mistletoes parasitic lifestyle makes a study of its synecology a little more complex. This is because its distribution patterns are super imposed on those of its host. Barlow (1981) suggests that the Australian *Loranthaceae* are largely independent of many of the parameters such as soil type, rainfall, etc., which determine the structure and distribution of terrestrial plant communities. Many Australian mistletoes have extensive ranges and occur in a number of communities which are different in terms of their ecological parameters. This indicates the habitat of Australian mistletoe species is primarily determined by the presence or absence of a suitable host. In New Zealand the geographical range of pirita appears to show a general association with that of its principal host genus *Nothofagus* and in particular *N. menziesi*. However, within the broad range of its host, other environmental factors may limit mistletoe abundance. Barlow (1974) for example found that altitudinal zonation was very prominent in the distribution of mistletoe species in New Guinea and that this pattern was largely independent of host distribution .

3.1.1 Study aims

1) To determine the density and distribution of pirita within silver beech forest in the Thomas Valley.

2) If distribution is not uniform, to identify which factors are associated with observed variability and assess which may cause it.

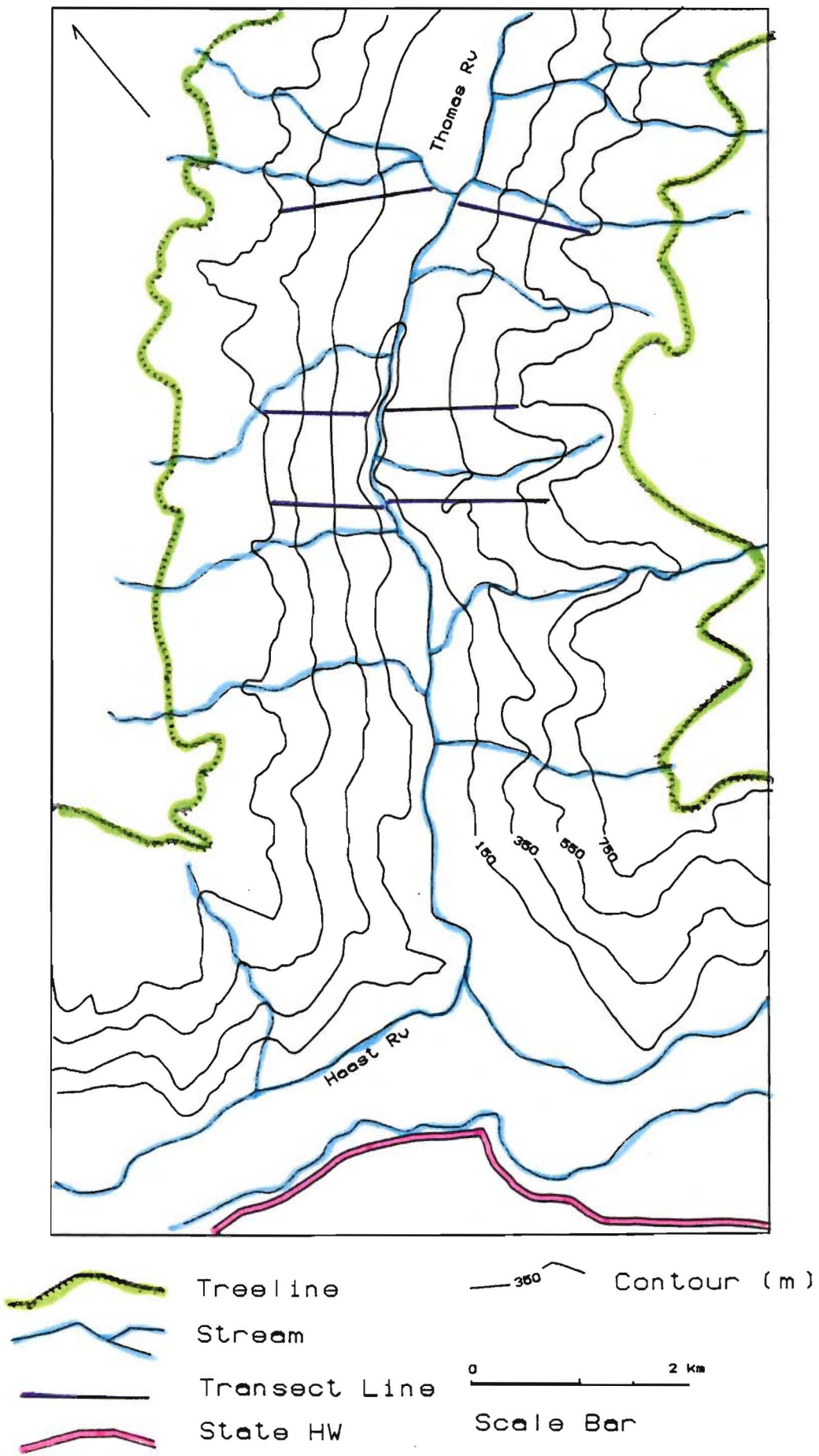
3.2 Study area and site selection

The study was undertaken in the Thomas river valley (see Figure 2.1). This area was selected because it contains large tracts of forest relatively unmodified by the activities of humans or possums (G. McDonald, pers. comm.). Sampling took place along transect lines which were positioned so a range of landforms (terrace, ridge, face, etc.) and aspects would be surveyed (Figure 3.1).

Possums

Possums are at very low densities (< 1/ha.) and are as yet unlikely to have had any impact mistletoe populations (see Introduction, Chapter one).

Figure 3.1 Thomas River Study Area



3.3 Methods

3.3.1 Field methodology

Sample plots were systematically located along 6 transects at 200 m intervals. Each 50 x 20m plot was laid out perpendicular to the transect. Sampling generally continued along each transect until the altitudinal limit of pirita was reached. This was based on reconnaissance of forest at higher elevation than the previous plot. Six transects were completed sampling a total forest area of 3.7 ha., plot altitudes ranged from 180 m to 730 m above sea level.

Within each plot the following information was recorded:

1) DBH (diameter at 1.4m) of every stem >15cm dbh.

2) Altitude, aspect, and plot topography.

3) Number of mistletoe plants on each stem.

4) Mistletoe height: the height of each host stem was estimated in metres and mistletoe plants placed in one of four height categories) (Figure 3.3).

5) Mistletoe size: plants were placed in one of the following four size categories:

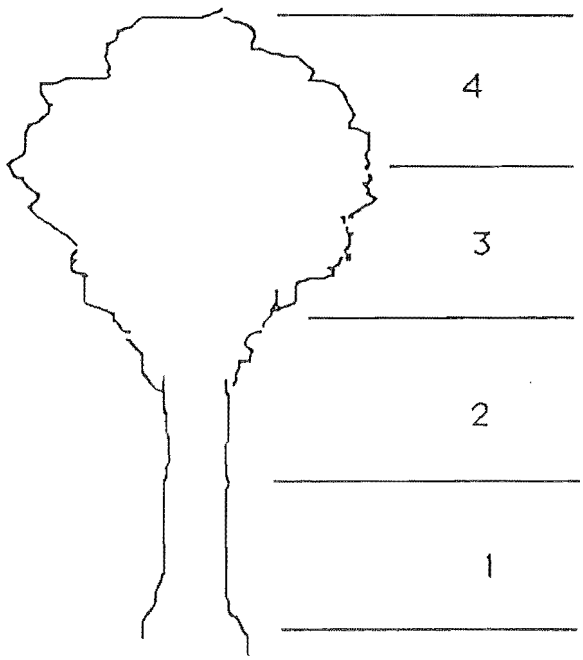
i) juvenile: plant consists of one or two small shoots or twigs.

ii) small: several twigs but no "thick" branches have formed.

iii) medium: a thick central branch has formed with some smaller side branches.

iv) large: several large axial branches with numerous side branches (plants typically 1.5-2.0 m diameter).

Figure 3.2 Mistletoe height classes.



3.3.2 Data analysis

Chi-square test of Independence

To determine host size preferences a chi-square test was used to determine if mistletoe densities occurring on different sized beech trees were independent of:

a) the dbh size class frequency of beech stems.

b) basal area of each size class

The 4 beech stem size classes used were:

1) 15-39 cm (dbh)
2) 40-64 cm
3) 65-89 cm
4) 90+ cm

Altitudinal patterns

Variation in pirita densities were examined among six altitude classes using a chi-square test of independence.

Classification of plots by TWINSPAN.

By identifying different forest types and comparing mistletoe densities, the influence of forest composition and structure on mistletoe abundance was investigated.

A classification technique (Two-way species indicator analysis) was used as implemented in the program TWINSPAN. Indicator species analysis classified plots into groups according to their degree of similarity in species composition.

In this case identifying broad forest types based on the frequencies within each plot of three tree species, ie. silver beech, kamahi, and southern rata. Eigenvalues were used to indicate the strength of the divisions.

Stem frequency data for each species were entered in one of four diameter size classes (15-39 cm, 40-64 cm, 65-89 cm, or 90+ cm). In this way analysis was sensitive to variation in forest age size structure.

Differences in mistletoe density between forest types.

Duncans multiple range test (using PROC GLM in SAS) was carried out to determine if there were differences in mistletoe densities among forest types identified by TWINSPAN.

Regression

Using simple linear regression, levels of host infestation (number of mistletoe plants/host stem/plot) were compared to the following environmental variables:

a) average size of silver beech in each plot

b) total basal area of silver beech

c) total basal area of all species

d) beech stem density

3.4 Results

3.4.1 Host preferences

Mistletoe abundance within dbh size classes

Pirita was not randomly distributed amongst potential host tree sizes. Chi-square results show that within silver beech forest, large trees are parasitised significantly more often than the numerically more abundant small stems. Pirita was 3.6 times more abundant than expected in the 90+ cm dbh host size class and 7 times less abundant than expected in the 15-39 cm dbh class (X^2= 146.6, $P < .0.001$). Figure 3.3a illustrates this pattern. Large trees (over 65 cm dbh) made up only 33.2% of all beech stems but hosted 84.3 % of pirita.

Mistletoe abundance and basal of dbh size classes

When data from all plots is combined pirita appear to occupy each host size class in proportion to its basal area (Figure 3.3b). The results of the chi-square test confirmed occurrence in each size class was not independent of beech basal area (X^2= 3.4, $P > 0.1$). This result reflects the fact the largest diameter trees contain proportionally most of the basal area.

Figure 3.3a Silver beech stem and mistletoe frequency by dbh size class (all plots).

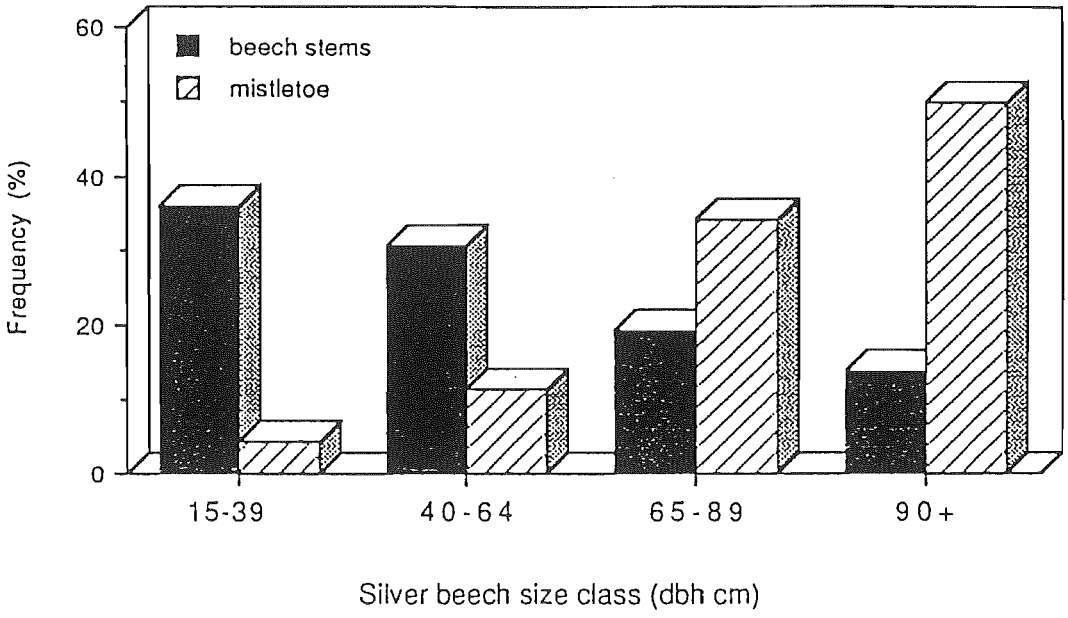
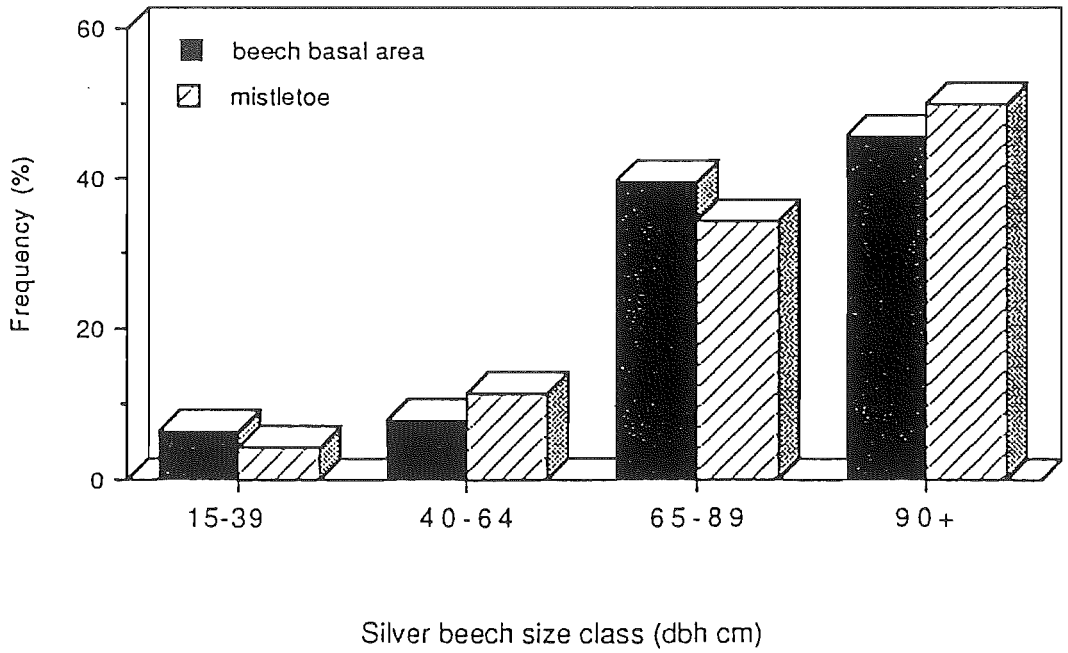


Figure 3.3b Silver beech basal area and mistletoe frequency by dbh size class (all plots).



3.4.2 Classification of plots into forest types by TWINSPAN

Indicator species analysis clustered plots into 4 groups. The strength of eigenvalues, (0.285 for first division and 0.200 and 0.343 for the two subsequent divisions) suggest the TWINSPAN groupings represent 4 distinct forest types. All forest types have a silver beech component, however the density and structure of the beech component varies as does the abundance and composition of associated species. The following descriptions are based on stem frequency data (Figures 3.4a, 3.4b, 3.4c, 3.4d) and field descriptions made of each plot.

1) Beech-broadleaved forest. (Figure 3.4a) (n=19 plots)

Large scattered silver beech trees (often >100 cm dbh) emergent or forming a tall multi-tiered canopy over a kamahi understorey. Large scattered podocarps (mainly miro and rimu) present below 350m. The small tree layer is often diverse containing, broadleaf, wineberry, fuchsia, pate, *Pseudopanax* species and younger silver beech. This forest type occurred predominantly on slope faces at low to mid altitudes.

Mistletoe plants/ha.= 36.0

2) Simple Silver Beech forest. (Figure 3.4b) (n=12 plots)

Dense stands of silver beech trees form a tall closed canopy. Kamahi, (at lower altitude sites), lancewood, and broadleaf sometimes occur in the small tree layer but the understorey is generally less diverse than type 1). This forest type dominated river terrace sites and at higher altitudes in plots which were in, or approaching montane silver beech associations described by Mark (1977).

Mistletoe plants/hectare = 6.0

3) Kamahi-beech-rata forest. (Figure 3.4c) (n=5 plots)

Kamahi and moderately sized beech trees are co-dominant in a continuous, low (12-16 m) canopy. Rata is moderately important and pokaka (*Elaeocarpus hookerianus*) and mountain celery pine (*Phyllocladus alpinus*) occur on wetter sites. This forest type included 4 plots located on a broad ridge where drainage was sometimes impeded. The understorey was generally sparse but when present dominated by horopito. Moss generally formed a thick continuous ground cover.

Mistletoe plants/hectare = 8.0

4) Rata-kamahi forest. (Figure 3.4d) (n=1 plot)

Rata and kamahi are co-dominant and scattered large silver beech is also present in a tall canopy. A sub canopy or small tree layer is absent but tree ferns and coprosma species form a dense shrub layer This forest type occurred in only one plot which was located on a low ridge which had formed on a large outwash surface.

Mistletoe plants/hectare =0.0

Figure 3.4 Density distributions (stems/ha) of silver beech, kamahi, & southern rata in forest types identified by TWINSPAN.

Figure 3.4a Silver beech-broadleaved forest. (mistletoe/ha=36)

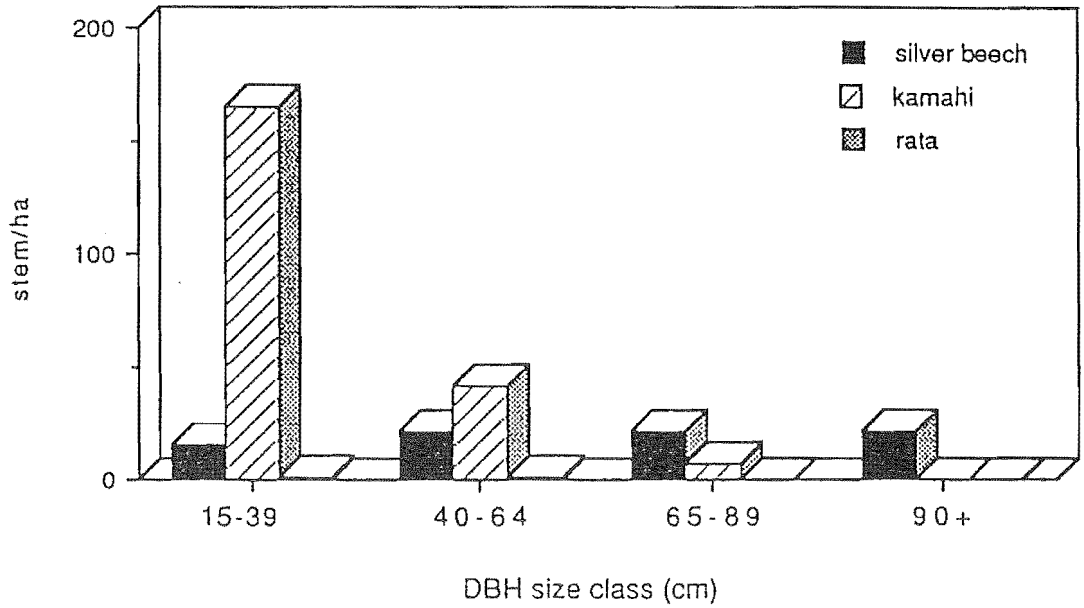


Figure 3.4b Simple silver beech forest. (mistletoe/ha=6)

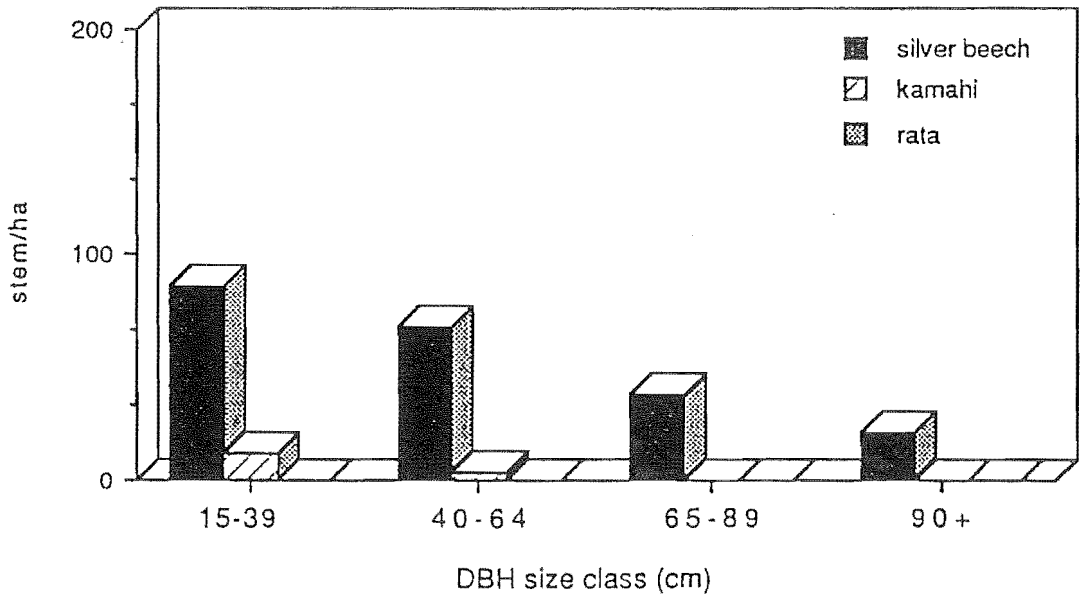


Figure 3.4c Kamahi-beech-rata forest. (mistletoe/ha=8)

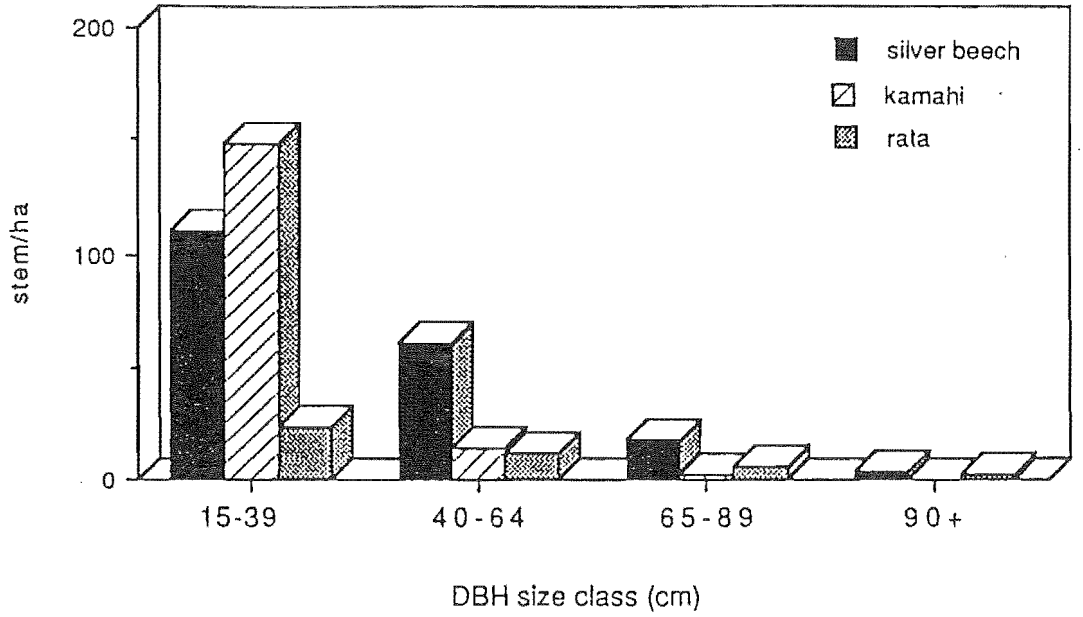
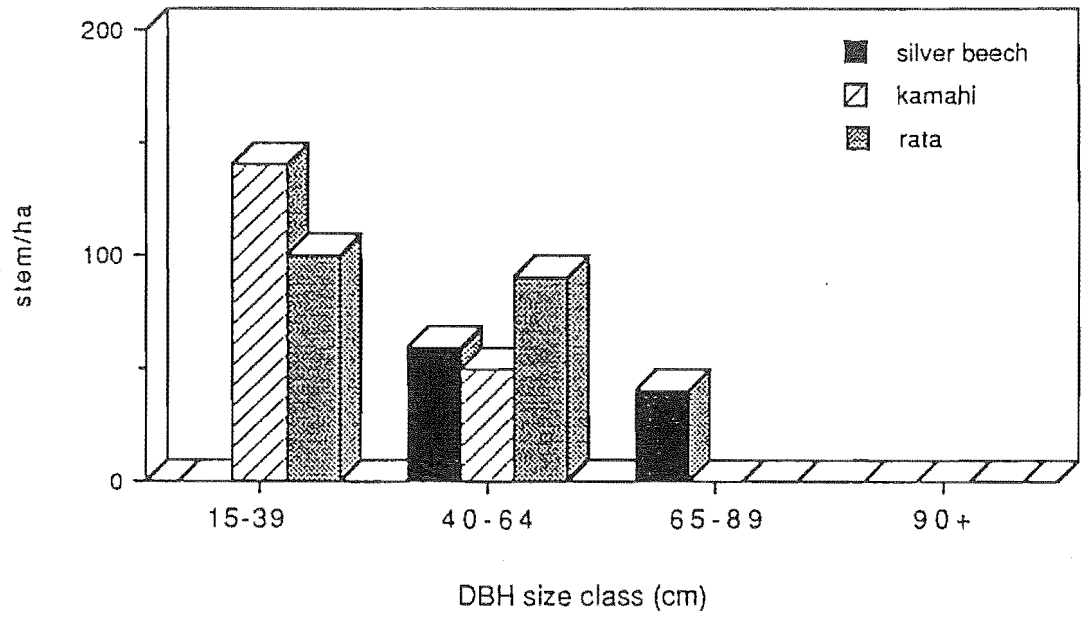


Figure 3.4d Rata-kamahi-beech forest. (mistletoe/ha=0)



3.4.3 Differences in mistletoe density between forest types.

Mean mistletoe densities in Beech-broadleaved forest were significantly higher than that of Simple beech forest and Kamahi-beech-rata forest (Figure 3.5). The mistletoe densities in Beech forest and Kamahi-beech-rata forest were not significantly different (Figure 3.5). Rata-kamahi-beech forest was not included in the analysis as it occurred in only one plot and contained no mistletoe.

A summary of the relative forest area and proportion of mistletoe contained in each forest type is made in Table 3.1. Beech-broadleaved forest covered just over half of the forest area sampled, contained 32% of potential host stems (ie silver beech), and 86% of mistletoe. In contrast Simple silver beech forest provided 51% of silver beech stems, covered 32.4 % of forest area but contained only 8.2% of mistletoe plants. Kamahi-beech-rata forest covered 13.5% of the area sampled and contained 5.5 % of mistletoe, and Rata-kamahi-beech forest covered just under 3% of the area and supported no mistletoe.

Figure 3.5 Mean mistletoe density in forest types (Rata-kamahi-beech forest contained no mistletoe and was not included in the analysis of variance).Values not joined by a continous line are significantly different (P<0.05)

Forest types:

1) Silver beech-broadleaved forest

2) Simple silver beech forest

3) Kamahi-beech-rata forest

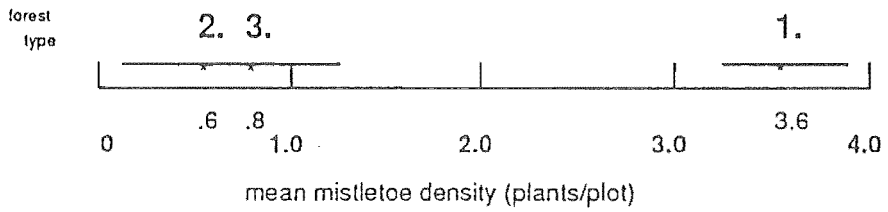


Table 3.1 Proportion of forest area, potential host stems (silver beech) and mistletoe contained in each forest type.

Forest type	% Forest area	% host stems (silver beech)	% mistletoe
Beech-broadleaf	51.4	31.8	86.0
Simple beech	32.4	50.9	8.2
Kamahi-beech-rata	13.5	15.4	5.5
Rata-kamahi-beech	2.7	2.0	0.0

3.4.4 Differences in mistetoe host size selection between forest types.

Mistletoe was present in all beech size classes occurring within Silver beech-broadleaved forest (Figure 3.6a), with highest mistletoe frequencies occurring on large beech trees (>65 cm dbh). In the other forest types (Figures 3.6b & 3.6c) mistletoe was absent from the smallest beech size class (<40 cm dbh) occurring only on larger trees. In all forest types, highest frequencies occurred in the two largest host size classes.

In kamahi-beech-rata forest the frequency of large beech trees (over 65 cm dbh) was low as were mistletoe frequencies. Simple beech forest contained relatively high numbers of large beech stems but mistletoe abundance remained lower in this forest type than it was in Beech-broadleaved or Kamahi-beech-rata forest (although. not significantly lower in the latter case)

Figure 3.6 Distribution of mistletoe and silver beech stems in forest types identified by TWINSPAN.

Figure 3.6a Silver beech-broadleaved forest

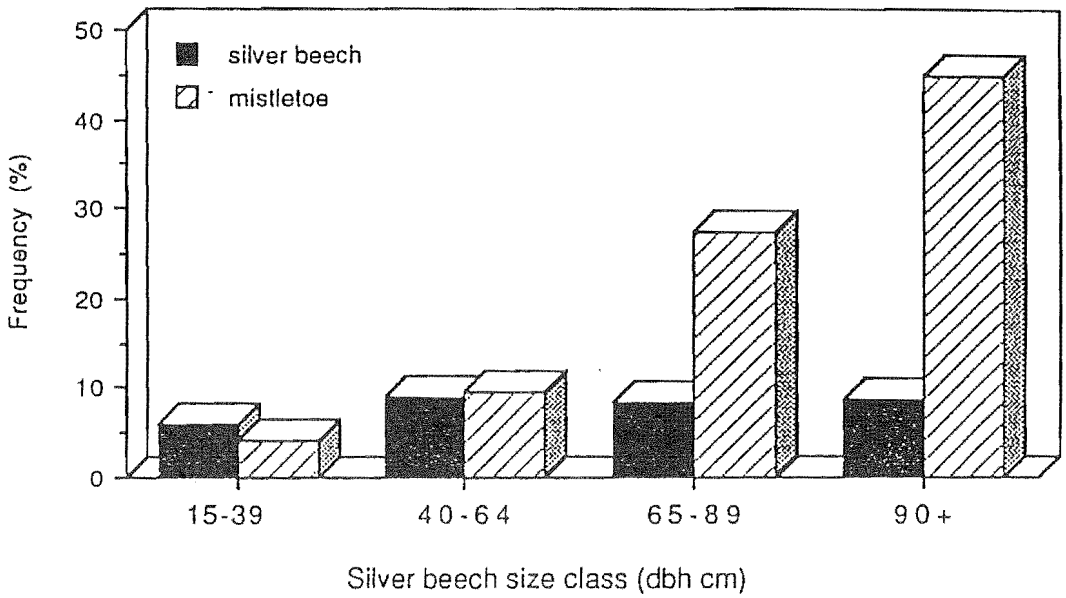


Figure 3.6b Simple silver beech forest

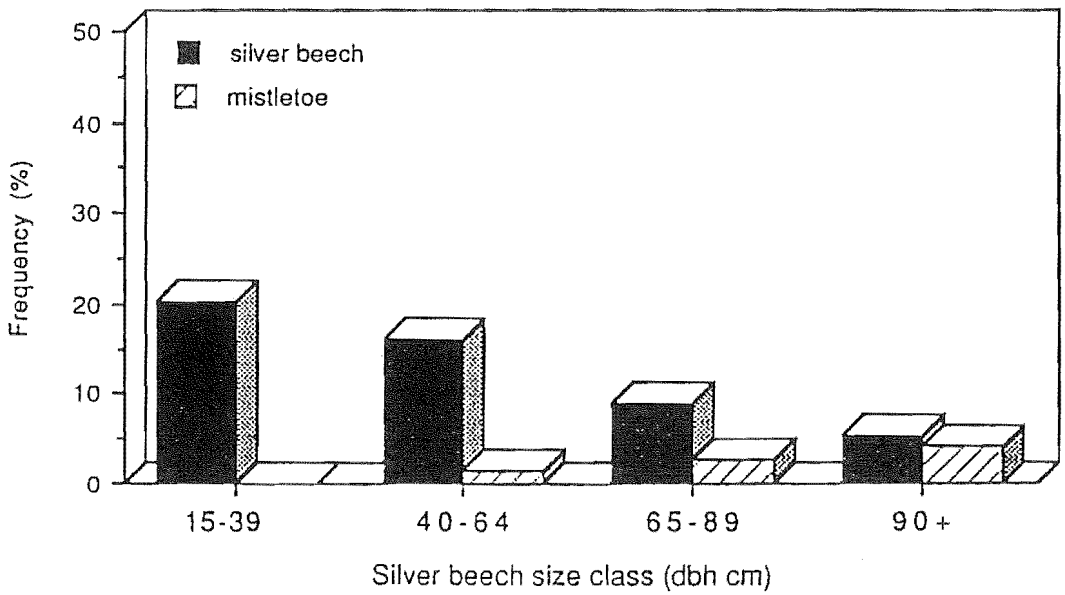
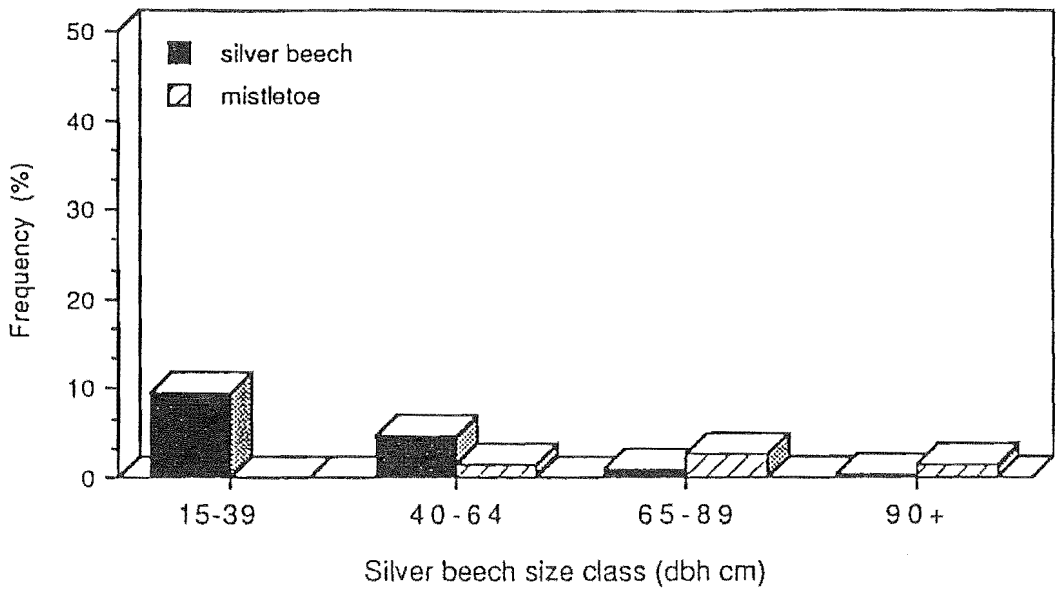


Figure 3.6c Kamahi-beech-rata forest



3.4.5 Distribution of mistletoe.

Vertical distribution of mistletoe in forest strata.

Mistletoe was not evenly distributed through the forest profile and there was a strong bias towards the upper height tiers.(Figure 3.7a). (As expected given the large proportion of silver beech biomass in the upper strata). When distribution patterns in Beech-broadleaf forest are compared to other forest types (Figures 3.7b & 3.7c.) a stronger bias towards the upper height tiers is evident in the other forest types. Of the mistletoe occurring in Beech-broadleaf forest 49 % grew in the top forest tier, the comparative figure for the other forest types was 73 %.

The spatial patchiness of mistletoe distribution.

The variation in mistletoe density between forest types demonstrates clearly that pirita is not evenly distributed in silver beech forest. Of the 37 plots sampled, mistletoe was absent from 16, and 66% of mistletoe plants occurred in just 6 plots.

Size distribution of mistletoe population

The size distribution of pirita was heavily weighted towards larger size classes (Figure 3.8). Only 3% of the mistletoes surveyed were juveniles, while 85% were classified as medium or large.plants.

It should be noted that younger and hence smaller, mistletoe plants are less conspicuous in the forest canopy than larger plants. There was potential therefore for a greater proportion of juvenile plants to remain undetected during canopy surveys. However, care was taken to thoroughly search all potential host trees to ensure any such bias was minimal.

Figure 3.7 Vertical distribution of Mistletoe within forest.

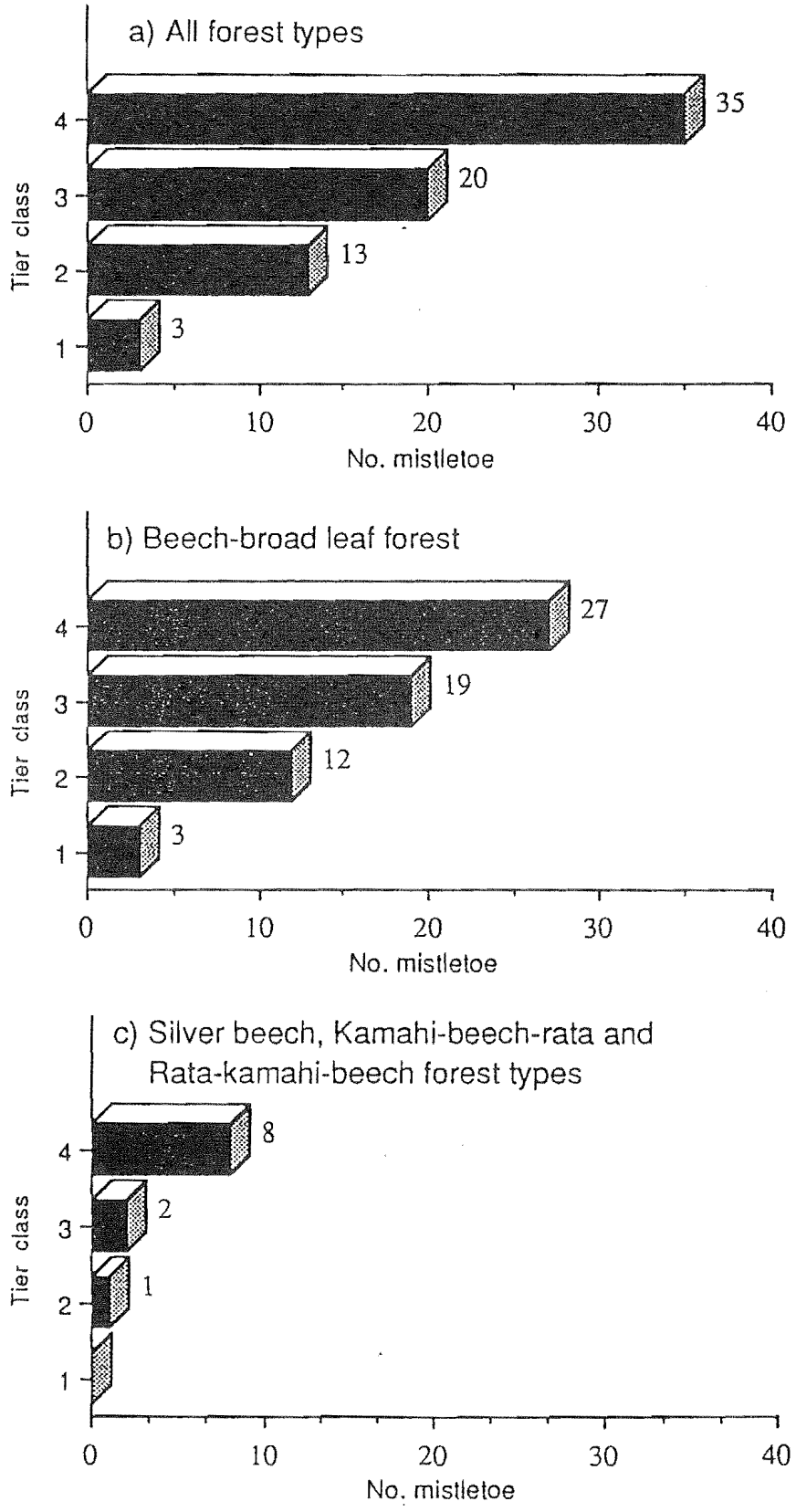
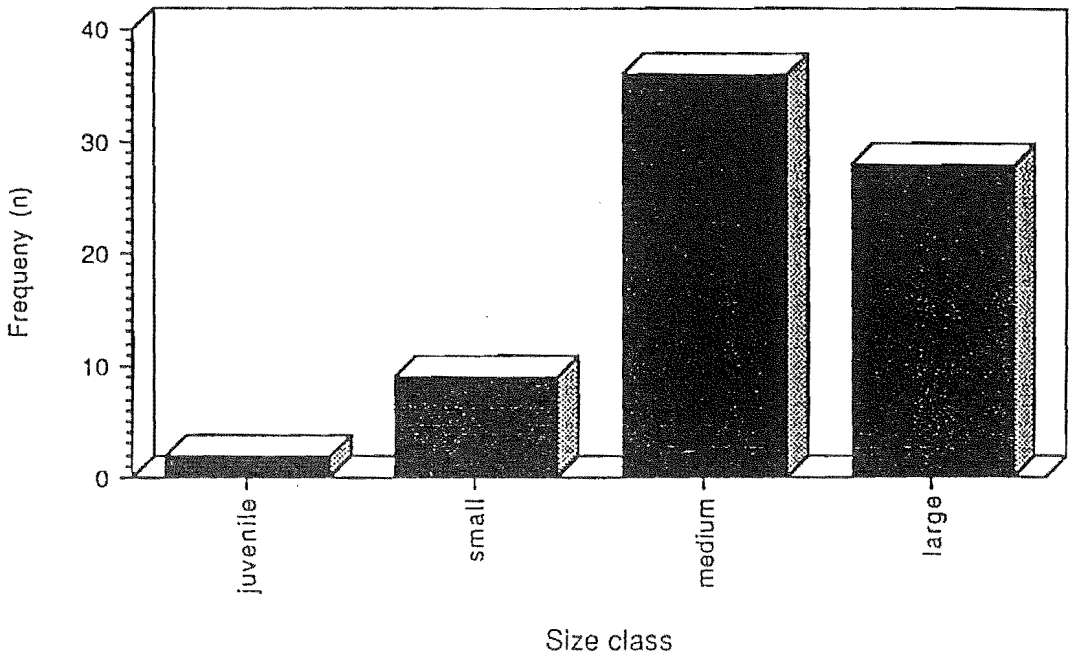


Figure 3.8 Size distribution of mistletoe in the Thomas Valley.



3.4.6 Physical variables and mistletoe abundance

Altitude

No linear relationship between altitude and mistletoe density was found (Figure 3.9). Pirita was however relatively abundant in plots which had an elevation of 250-450 m, and significantly less common in plots at lower and higher elevations (X^2= 22.8, P > 0.001). On transect lines pirita was not recorded above 680 m, it was however observed in adjacent forest at 750 m. At higher altitudes low but apparently increasing densities of the smaller mistletoe, pirirangi were encountered

Aspect

There was no significant difference in mistletoe density between plots which faced North-West and those facing South-East ie. average densities on both sides of the valley were around 2 mistletoe/ha (Table 3.2).

Topography

Systematic sampling provided an approximately proportional sample of face, ridge, and terrace landforms. However, because only 37 plots were completed, sampling of ridge and terrace sites was not extensive enough to allow statistical comparisons of mistletoe density. Variation in the small data set requires caution in any interpretation. There is some indication however that mistletoe densities are higher in forest growing on slope faces than on ridge or terrace sites (see Table 3.3). If this distribution pattern does occur it may correlate with the variations in forest types across these surfaces (see section 3.4.2).

Figure 3.9 Altitudinal distribution of mistletoe in the Thomas valley (error bars are +- one standard deviation).

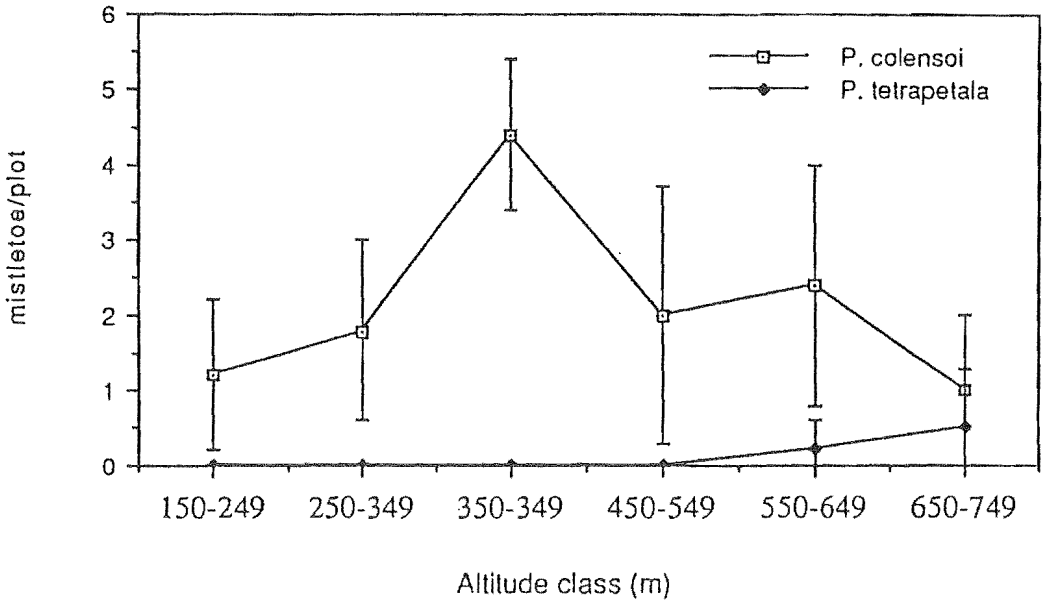


Table 3.2 Forest aspect and mistletoe density (densities are mean number of mistletoe per plot +- one standard deviation).

Aspect	No. plots	Mistletoe density
North-west	18	2.1+-0.8
South-east	19	1.9+-0.6

Table 3.3 Physiography and mistletoe density (densities are mean number of mistletoe per plot +- one standard deviation).

Physiography	No. plots	Mistletoe density
face	25	2.6+-3.3
ridge	5	0.8+-1.2
terrace	7	0.7+-1.2

3.4.7 Regressions

Simple linear regressions were performed comparing mistletoe infestation (mistletoe/beech stem) in each plot with the following variables:

1) Mistletoe infestation Vs mean host size

There was a positive relationship between host size (average silver beech basal area/plot) and the frequency of mistletoe. Plots containing on average larger trees tended to have a higher frequency of mistletoe infestation ($P= 0.001$, $R^2=0.489$) (Table 3.4.).

2) Mistletoe infestation Vs total basal area

Plots with a high total basal area tended to have more mistletoe ($P<0.05$, $R^2=0.143$) (Table 3.4.).

3) Mistletoe infestation Vs host stem density

There was a significant negative relationship between the number of beech stems in a plot and the rate of mistletoe infestation ($P<0.01$, $R^2=0.271$) (Table 3.4.) ie. plots with high silver beech stem densities contained fewer mistletoe per stem.

4) Mistletoe infestation Vs beech basal area

There was no apparent relationship between the levels of mistletoe infestation and total silver beech basal area in each plot. Mistletoe it seemed were no more abundant in plots with a high beech basal area than they were in plots with low beech basal area.

Table 3.4 Regression equations for pirita infestation (pirita/host stem/plot) and four plot variables, showing level of signifigance (P) and proportion of variation accounted for (R^2).

Regression	Equation	P<	R^2
1) mistletoe infestation X mean host size	Y= 1.187x -.179	0.001	0.489
2) mistletoe infestation X total basal area	Y=.069 + -.285	0.05	0.143
3) mistletoe infestation X density of host stems	Y= -.028x + .655	0.01	0.271
4) mistletoe infestation X host basal area	Y= -.007 + .291	n.s	0.001

3.5 Discussion

3.5.1 Mistletoe density as a function of time and host size

One of the obvious patterns in the relationship between pirita and silver beech is the mistletoes preference for large host trees. Chi-square results showed that within beech forest large trees are parasitised far more often than numerically more abundant small stems. Similar correlations between host size and the number of mistletoes per tree have been established for various host mistletoe combinations (eg. Lamont & Southhall, 1982; Hoffman, *et al.* ,1986; Reid & Lange, 1988)

The simplest models to account for this pattern of host selection assume that as potential host trees grow they accumulate mistletoes as a function of time and host canopy size (Reid & Lange, 1988). Both factors probably play a role in the relationship between pirita and silver beech in the Thomas valley.

a) Size

Although less abundant, large silver beech stems trees provided majority of forest basal area and presumably a proportionately large amount of the crown and especially branch area available for mistletoe establishment.

b) Time

Other factors being equal, the longer any potential host surface spends in an environment the greater are its chances of being infested by mistletoe. This suggests that a large old tree is a more likely host than a younger tree of the same dimensions.

Given the relationship between increasing silver beech age and size (Herbert,1972), the two phenomena, tree size and age, probably combine to

direct selection towards larger hosts. These selective forces produce the close relationship between host basal area and mistletoe infestation seen in Thomas valley.

3.5.2 Mistletoe and beech forest structure

As already shown, pirita has a preference for large trees, and its distribution within the forest is to a certain extent related to the distribution and density of large host trees. However the distribution and abundance of large host trees alone does not fully explain observed patterns of mistletoe abundance. For example, large beech stems are at least as common in Simple beech forest as they are in Beech-broadleaved forest, and yet the latter forest type contains significantly more mistletoe. It appears that pirita occurs preferentially on large beech trees, but in particular trees associated with a certain forest structure. It would therefore seem probable that the principal factors determining mistletoe distribution and abundance in silver beech forest relate to temporal and spatial variations in forest structure. Given that variations in beech forest structure are a function of forest disturbance and regeneration, the distribution of mistletoe must be intimately linked to these dynamic forest processes.

Silver beech forest structure and dynamics

To better understand the factors responsible for mistletoe distribution some knowledge of disturbance and regeneration processes within silver beech forest is required.

In general, the regeneration of beech in New Zealand follows a whole stand replacement process in which even-aged stands develop in large gaps after disturbances such as mass movement, extensive windthrow, insect or snow damage (Cockayne, 1926; Wardle, 1984). Although massive disturbance is also

a feature of other New Zealand forest types, for example, in lowland Podocarp forest (Duncan, 1991) many of the species in these forests have greater shade tolerance and regenerate in smaller canopy openings resulting from more frequent small scale disturbances (Stewart & Veblen, 1982; Cornere, 1992).

Mixed silver beech forest has been described as transitional between these two formations (Stewart,1986), showing a differential response to major, infrequent and minor frequent disturbance. These differences in response are expressed in the structure of the forest that develops. Frequently disturbed mixed beech forest tends to be multi-tiered and contains beech canopy trees of varying heights with wide-spreading crowns, and abundant canopy openings. A range of shrub hardwoods occur within this forest along with kamahi and silver beech (Stewart,1986). In contrast forests which have arisen after major disturbance (with little recent disturbance) have dense even canopies, contain straight relatively unbranched beech stems, and few canopy openings(Stewart,1986).

At higher altitudes and on river terraces in the Thomas valley "Simple silver beech forest" was the dominant forest type. It seems probable much of this forest has established after large scale disturbance, such as major floods on the terraces, or mass movement on upper slopes. There are clear structural similarities between this forest type and that which develops after infrequent but large scale disturbance according to Stewart's (1986) model. There are also obvious similarities between the structure of frequently disturbed forests described by Stewart (1986) and the Beech-broadleaved forests identified by TWINSPAN.

The abundance of pirita within the Thomas Valley appears to follow a structural gradient in the forest. At one end of this gradient where mistletoe

densities are highest, are diverse, open canopied, all-aged stands. At the other end are dense canopied, even-aged, beech forest which contains little or no mistletoe. As these latter stands age they tend towards a frequently disturbed forest structure (Wardle & Allen, 1983) and as time passes could be expected to contain higher densities of mistletoe.

The simple model outlined above describes the role silver beech dynamics may play in influencing the distribution of pirita. Only with a greater knowledge of the regeneration ecology of mistletoe can the other factors influencing its density and distribution be fully understood.

Why is forest structure so important to mistletoe?

Unfortunately there is no published information and little known about the conditions pirita requires for its establishment and growth. Overseas studies have shown that while some mistletoe species are not light sensitive (eg. Lamont & Southhall, 1982), many are and require high light levels for the successful germination of seeds. As a consequence many species have a preference for high tree tops, open stands, or the edges of dense forest (Gill & Hawksworth, 1961).

The distribution of pirita amongst forest height tiers showed a very strong bias towards the upper canopy. This distribution undoubtedly relates to the availability of suitable sites for establishment and growth. The upper forest strata contain most of the hosts small twigs and foliage (Beets, 1980) and also receive higher light levels. Mistletoe's bias towards the upper canopy was pronounced in Beech-broadleaved forest but markedly less so than in the other less structurally diverse forest types. This suggests that light levels are not as limiting beneath the canopy of Beech-broaleaved forest. The vigorous understorey and in particular the presence of light demanding seral species

certainly indicated that this forest was a relatively well lit environment. The presence of mistletoe on a wide range of host sizes including sub-canopy trees also indicates that conditions were favourable for the establishment and growth of mistletoe within several tiers of the forest.

Patchy distributions of mistletoe populations are a frequently observed phenomena (Reid & Lange, 1988). It is suggested that two possible factors are responsible for "concentrated pockets" or contagious distributions of mistletoe. Firstly, individual hosts may differ genetically in their susceptibility to infestation, and therefore susceptible individuals accrue a disproportionate number of mistletoes. Secondly, the "seed shadow" of individual mistletoes is largely restricted to the canopy of the host tree, both in mistletoes with mechanically discharged seeds and bird-dispersed species. Unfortunately there is no information to evaluate the influence of generic variation in host silver beech. It does seem likely however that piritas' clumped distribution is linked to the nature of its seed dispersal. When plants establish in a favourable habitat a limited seed shadow would reinforce the bias in their distribution around infested trees and forest stands. Birds are assumed to play a role in the dispersal of pirita (as they do in the dispersal of many mistletoe species overseas, (eg.Gill & Hawksworth, 1961; Davidar, 1983; Reid, 1986) there is no specific information for New Zealand. Diverse old growth beech forest containing mistletoe are a preferred feeding habitat of kaka and many other forest birds in south Westland (O'Donnel & Dilks,1986). If birds are involved in mistletoe dispersal their spatially concentrated feeding activity could be a factor in the clumped distributions observed in this study (c.f Reid, 1989).

Size distribution within the mistletoe population

Very few mistletoe "seedlings" were recorded in the Thomas Valley (possibly because of their size a significant proportion were unobserved). Even with this

sampling bias taken into consideration it is apparent that the populations size distribution is dominated by larger individuals. Although a size-age relationship for pirita has not been established it seems probable that the populations size distribution atleast in part reflects its age structure. If such a size-age relationship does exist then the present population structure appears dominated by mature plants.

Two possible explanations for this phenomena are discussed below:

Mistletoe regeneration in the Thomas Valley may be intermitent, large cohorts of mistletoe may only develop when habitat conditions are favourable. The current concentration of mistletoe in larger size classes may be the result of a cohort arising from a past regeneration pulse triggered by an event such as widespread stand senesence and associated opening up of the beech canopy. However, such a theory does not explain why in forest stands which are currently open in structure and appear favourable to regeneration mistletoe seedlings are not presently abundant.

A second possibility is that the current lack of regeneration is not "natural" but relates to a decline in pollination and/or seed dispersal agents such as the nectar feeding kaka or the partly frugivorous yellow head (O' Donnel & Dilks, 1986).

Unfortunately without an accurate ageing of the pirita population and more knowledge of its reproductive biology these theories remain speculative.

3.5.3 Influence of other environmental variables

Aspect

Mistletoe distribution did not appear to be influenced by plot aspect. Although it is hypothesized that pirita is sensitive to variation in the forest light environments, differences in microclimate between north-west and south-east facing slopes of the Thomas Valley were apparently not great enough to affect its distribution.

Topography

Because of small sample sizes and variability in the data set the influence of topography is not clear. There is some indication that lower mistletoe densities occur on terrace and ridge sites. If this pattern does exist it may relate to the influence these landforms have on forest structure Stewart (1986) found that silver beech forest growing on river terraces tended to be dense canopied and even aged. On spurs and ridges, Wardle (1991) notes that beech canopies tend to be continuous with little vegetation beneath. He went on to say that along the gradient from ridges across onto faces (where mistletoe densities appear highest) the lower tiers become denser and beech trees larger and further apart.

Altitude

The altitudinal limit of Pirita in the Thomas valley appeared well below that of silver beech. In the Thomas Valley, treeline is around 1100 m (Mark,1977) while the distribution of prita appears to be largely restricted to forest below about 700m. The small but increasing numbers of piririangi encountered at higher altitudes suggests some form of altitudinal niche separation. The absolute altitudinal limit of either species in the Thomas valley was not

determined. In most plants this limit is set by the interactions of climate and plant growth and development (Tranquillini, 1979).

In north-west Nelson, pirita were recorded growing at elevations above 900 .m and pirirangi were still common above 1200 m (Wilson, 1984). These patterns suggest that latitude may have some influence on the altitudinal distribution of pirita, as it does on the altitude of the beech timberline.

The abundance of pirita was not constant over the elevations sampled. It was most common in the old growth forest of mid altitude slopes and less common at both higher and lower altitudes. It seems probable that within the altitudinal range of this study the direct influence of altitude (ie. climate related gradients) was minimal.

What affect altitude has on pirita distribution in the Thomas Valley is probably expressed indirectly through its influence on forest structure. The general pattern in beech forest is that at higher altitudes tree size is smaller and the density of stems is greater than at lower altitudes (Wardle, 1984). Higher stem frequencies, a lack of diversity and a more extreme climate may favour a dense and more even canopy than occurs at lower altitudes. As already discussed the structure of these stands may not provide an optimal habitat for pirita their dense even canopies possibly restricting light to limiting levels.

3.6 Conclusions

Host size and forest structure were two important factors found to be influencing mistletoe distribution in the Thomas valley.

Large beech trees were generally favoured as hosts by pirita, but large trees growing within a certain forest type appeared the most favoured hosts. It is possible that the influence of disturbance in stand development of Beech-broadleaved forest, (in particular the development of canopy gaps and a multi-tiered structure) create conditions favouring the establishment and growth of mistletoe.

The mistletoe population appears to contain a bias towards larger and possibly older plants. This bias may reflect the presence of a relatively even aged cohort, or perhaps pirita is naturally slow to mature. A third possibility is that some form of regeneration failure is occurring.

The altitiudinal limit of pirita appears to be significantly lower than that of its host silver beech. It is likely that its exact limit is determined by an interplay of direct physiological influences and indirect limitations arising from the predominance of simpler forest structures at higher elevations.

CHAPTER FOUR

Mistletoe Browse

Chapter outline: In this chapter previous methods of assessing possum damage in New Zealand indigenous forests are reviewed. A methodology is described which quantifies the leaf area on individual mistletoe plants removed by possums and insects. The extent of animal browse on individual plants and the sample population as a whole is then evaluated and finally the likely impact of this browse on mistletoe in the Haast Valley mistletoe population is discussed..

4.1 Introduction

Quantitatively measuring the impact of introduced herbivores on indigenous flora is important if efficient and effective pest management strategies are to be devised. The goal of any pest control operation should not be to kill animals *per se* but to limit or halt their impact on some value that we wish to protect (Parkes,1990). Mistletoe has been identified as a plant sensitive to the predation of possums (Wilson, 1984) and important to sustaining wildlife (O'Donnell & Dilks, 1986). The extent to which possums impact on mistletoe populations may indicate the degree of modification being incurred on broader ecosystem functions. In South Westland, the Department of Conservation have begun monitoring the health of mistletoe populations as a measure of the effectiveness of there possum control operations (James, 1990).

By quantifying current rates of possum herbivory in an area where no control is being undertaken valuable information on the sensitivity of mistletoe to possum predation in South Westland may be gained. From such information it should be possible to make predictions about the fate of mistletoe populations within South Westlands "no possum control" areas.

4.1.1 Study aims

1) To determine if possums are browsing mistletoe plants in the upper Haast Catchment.

2) If possum browse is occurring, identify its seasonal timing and the proportion of mistletoe plants affected

3) From a sample of plants, quantify changes in leaf area resulting from possum and/or insect browse, leaf abscission, and growth.

4.2 Study area and site selection

The diet study area was located in the upper Haast river catchment (Figure 2.1). Its general location and physical description are also covered in Chapter two.

Possums

Possums have probably been present in the area since the 1950's there populations are now established but still considered pre-peak (Rose *et al.*,1990) (see section 2.5 for further details of possum colonisation). It is also an area where possums are at relatively high densities (on a regional scale, Figure 2.2) and where no possum control operations were planned or had been recently undertaken by the Department of Conservation. (G. McDonald, pers comm.).

Site selection

Three basic criteria were applied in selecting the sites at which possum browse on mistletoe would be monitored:

1. Mistletoe should be common and accessible enough within the forest to enable a sample of plants to be regularly and intensively monitored.

2. Possum densities should be at the higher end of the range densities that occur in South Westland.

3. Floristically similar areas should be available from which possums can be removed (for gut analysis) without influencing population densities around the mistletoe monitoring sites (see chapter 5).

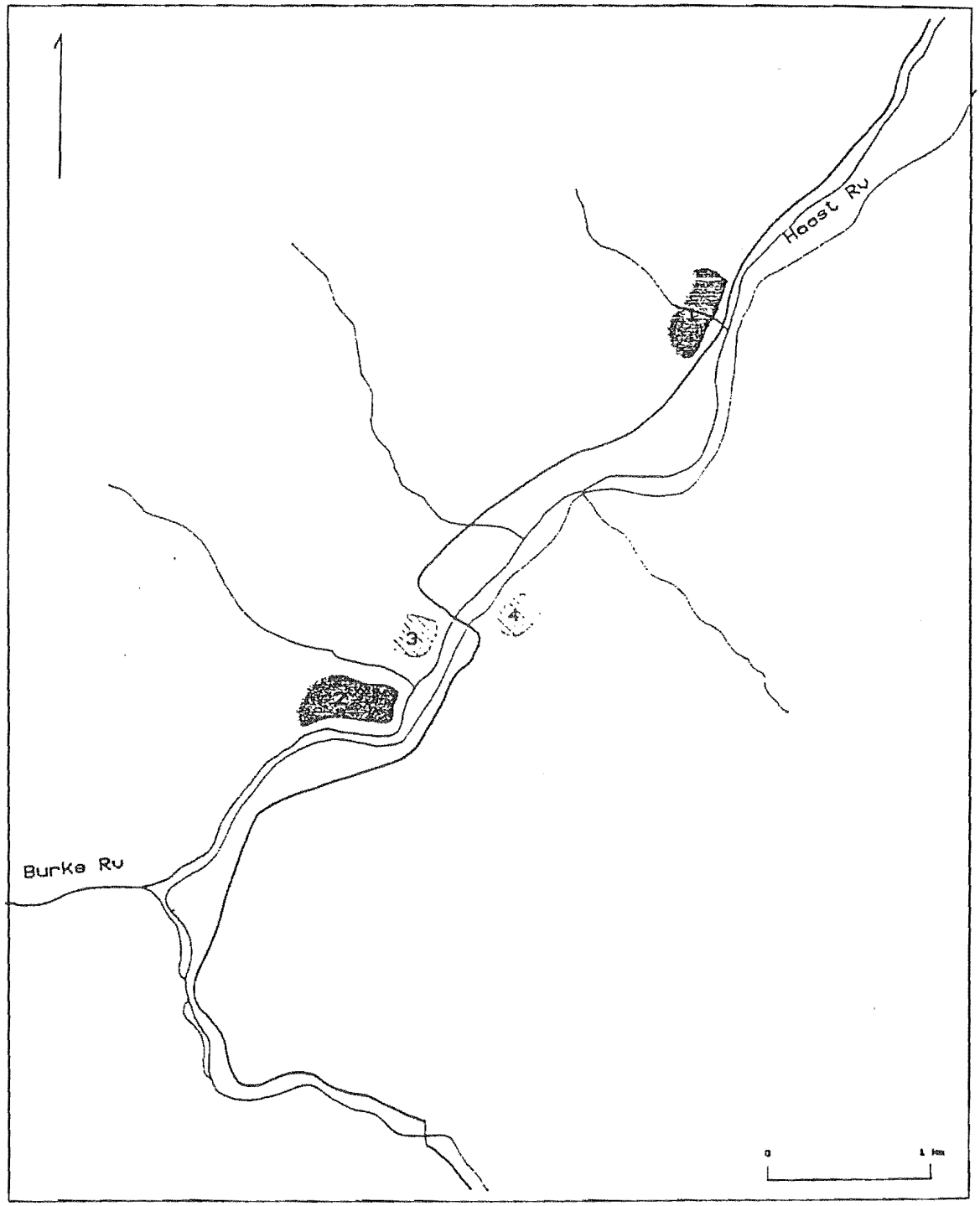
With respect to these criteria two suitable sites were identified within the Upper Haast study area (Figure 4.1).

1) Pleasant Flat.

2) Deer Stalkers Flat.

The landforms, soils, and vegetation of these sites follow the descriptions given in section 2.7. Forest structure, and possum and mistletoe densities are essentially identical at the two sites.

Figure 4.1 Upper Haast Study Area



Gut Collection sites

Mistletoe monitoring

State Highway

1) Moa Ck
2) Baker Ck
3) Pleasant Flat
4) Deer Stalkers

4.3.Review of methods

4.3.1 Methods of assessing possum damage

Several techniques have been used to assess the extent and impact of possum browse in New Zealand native forest. Most have been based on subjective visual assessments of tree or forest 'condition'.

Pekelhering (1979) compared levels of canopy defoliation in the Taramakau valley from aerial photographs taken in 1960 and 1973.

The amount of dieback in a forest canopy has also been assessed from helicopter then subjectively scored on some predetermined scale (eg. Pekelhering & Reynolds, 1983; Rose, *et al.* 1990).

If information is available on past and present possum densities techniques which visually assess canopy defoliation or dieback may provide circumstantial evidence linking forest dieback to possums. However, when assessment is based solely on defoliation and does not quantify the amount of possum browse, the processes which drive an observed dieback phenomena may remain open to interpretation. In the 1980's for example, there was debate as to whether widespread dieback of Westland rata-kamahi forest was primarily a result of possum browsing or due to natural stand dynamics.(see Veblen & Stewart, 1982; Batcheler,1984)

To better understand the possums role in tree death and dieback scientists have measured the amount of browse occurring on individual trees and investigated the effects of this browse on tree health (eg. Meads, 1976; Leutert, 1988.; Payton, 1983) To some extent these studies have provided the 'ground proofing' required to support the findings of larger scale surveys.

4.3.2 Relative subjectivity of techniques

A majority of ground based survey techniques rely on subjective estimates of the defoliation and/or possum browse present in a tree crown (eg. Meads, 1976; Wilson, 1984; Leutert, 1988).

Estimates of tree condition such as percentage defoliation or percentage browse scores are useful indicators of possum impact only when comparable information on the health or condition of unbrowsed trees is available. This requires knowledge of natural rates of tree defoliation and mortality.

Establishing the average 'state of health' (rate of mortality or growth) of a comparable population of unbrowsed trees is a difficult proposition. In theory it can be done by excluding possums from a random sample of trees. Rates of defoliation and mortality can then compared between trees from which possums are excluded and a sample of trees to which possums have access. This type of experimental design has been used by Coleman & Pekelhering (in prep.). The practical difficulties of isolating large numbers of trees however make it a costly procedure and one difficult to use on a large scale.

"Pest free" off shore islands are potential indicators of the natural rate of change (growth and dieback) in native forest. Comparative studies of vegetation condition may allow the impact of introduced herbivores to be measured (eg. Veblen and Stewart, 1980). However, there are a limited number of islands which are useful for this purpose ie. both botanically and geologically comparable to mainland habitat and free of the influences of other introduced herbivores.

A technique used by Coleman et al. (1980) to quantify possum browse was to tag twigs and numerically record the number of leaves present. Twigs were

periodically checked and the number of browsed leaves recorded.

Numerical assessment avoids some of the subjectivity associated with visually assessing defoliation. A disadvantage of the technique is its greater labour intensity. Trees must be climbed to enable an "in hand" assessment made of each tagged twig. This can be a time consuming and physically strenuous activity. These efforts however can be rewarded with accurate quantitative data on the amount and cause of any change in leaf area.

4.4 Methods

4.4.1 Field methodology

Browse identification

New Zealand forests contain several arboreal folivores (including the possum, and bird and insect species) all of which can have different affects on vegetation (Wardle, 1991). Observers need to be familiar with the browse patterns of these folivores if their activities and impacts are to be distinguished.

Meads (1976) compared insect and possum browse patterns on northern rata *Metrosideros robusta*. Typically possum browsed leaves were distinguished by torn and jagged leaf stubs; and insect browsing by the holes and wavy clean-edged patterns (caterpillars) or straight, finely milled edges (stick insects)

Before any assessment of mistletoe browse was carried out in the field, familiarity with patterns of browse were gained in a feeding trial. Captive possums housed at Forest Research Institute facilities in Rangiora were fed

mistletoe foliage and the browsed leaves examined.

The pattern of damage on mistletoe leaves fed to captive possums was similar to that described by Meads (1976) for northern rata. All that remained of most browsed leaves was a small torn piece of the leaf base. On some twigs, leaves were removed entirely.

Possum browse was easily identified in the field. Insect browse, even when severe enough to superficially resemble possum damage, could be readily distinguished with a close 'in hand' inspection. Browsing insects typically leave a cleanly cut leaf edge contrasting with the torn leaf edge that remained after a possum bite. They also tend to leave circular or semi-circuilar browse patterns on leaves which are easily distinguished from possum damage (Plate 1).

Tagging and Recording

Forty mistletoe plants were located in the Upper Haast River study area. (twenty plants at each site). Mistletoe plants were selected on the basis that they grew on separate host trees, and were accessible with the aid of climbing gear. Host trees were marked and mapped for relocation. Ten twigs (25-30 cm long) on each plant were selected at random and marked with a numbered aluminium tag. The position and number of leaves on each twig was drawn on a diagram. Each time a leaf was inspected a simple index was used to score its area and where possible, the cause of any defoliation ie. possum or insect browse (Figure 4.2).

Timing of sampling

The monitoring of 14 mistletoe plants at the Pleasant Flat (P.F) site commenced in November 1990. In February 1991 browse on these 14 plants

was re-measured and an additional 6 plants were tagged and scored.

At the Deer Stalkers (D.S) site monitoring of all 20 plants commenced in February 1991.

Changes in leaf area were assessed in February (for 14 of the P.F plants), May, August, and November of 1991.

Plate4.1 Mistletoe twig showing insect and possum browse. (photograph taken in February 1991). Note the circular pattern of insect browse on the current seasons leaves. Possum browse can be identified as the torn leaf bases, ie. all that remains of previous seasons growth on that twig.

Figure 4.2 Index used to score changes in mistletoe leaf area, (The prefix N indicates no browse, P possum browse, I insect browse, and A leaf abscissed).

Index Score	leaf area present
N	100 % 
P3 or I3	66-99 % 
P2 or I2	33-66 % 
P1 or I1	1-33 % 
A	0%

4.4.2 Data collection & analysis

Calculating leaf area and leaf area changes

By summing the initial index score of each leaf (100, 99, 66, 33, or 0 %) a total leaf area score was calculated for each plant. Changes in index scores over the sampling periods were used to calculate the leaf area each plant lost to insects, possum browse or leaf fall. The leaf area added to each plant by vegetative growth was also calculated

There was variation in the numbers of leaves present on each sampled twig and hence in the total number of leaves sampled from each plant. To allow comparisons of leaf area change to be made between plants, each plants initial leaf area was standardised to a score of 100, and subsequent leaf area changes were expressed as a percentage.

Comparing browsed and unbrowsed plants

Differences between leaf area loss, leaf area growth and net leaf area change were tested between browsed and unbrowsed plants. This was done using PROC TTEST on SAS with the Cochran and Cox (1950) approximation of the *t* statistic under the assumption of unequal variances.

Amongst browsed plants the relationship between the intensity of possum browse and plant vigour was investigated. To do this, simple linear regression was used to test the percentage of possum browsed leaves against each plants net leaf area change.

Phenology

The studies aim was not to provide detailed information on the phenology of mistletoes, moreover the sampling regime used was not frequent enough to

allow the collection of such data. However the plant monitoring did provide some quantitative information on the timing and quantity leaf growth and leaf fall.

4.5 Results

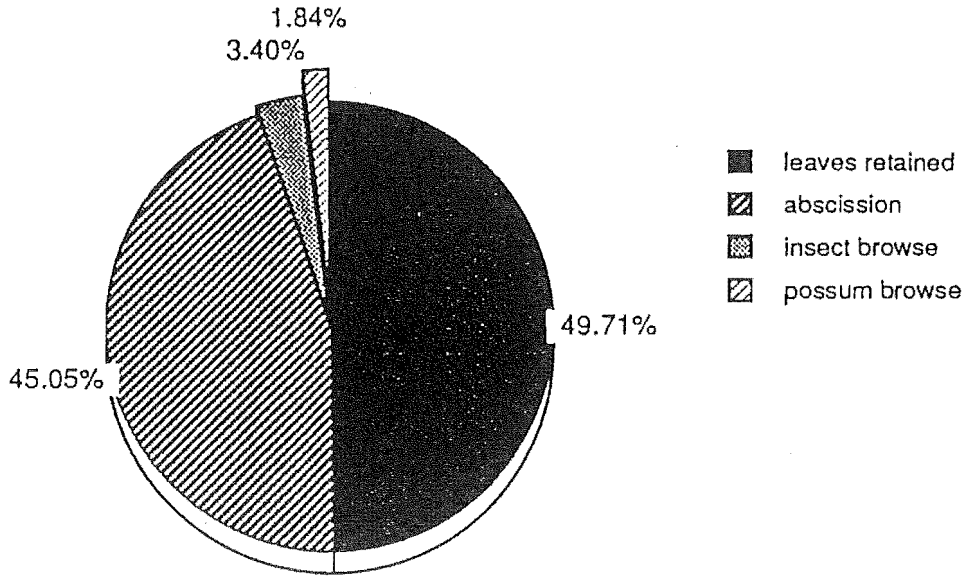
4.5.1 Overall patterns of leaf change at Pleasant and Deer Stalkers Flat

Data presented is based on leaves present in February 1991. Figure 4.3 illustrates that the patterns of leaf loss were similar at both sites. At Pleasant Flat (P.F) a total of 50.3 % (Table 4.1) of original leaf area was lost over the sampling period. At Deer.Stalkers Flat (D.S) the figure was 53.5% (Table 4.1). At both sites around 90 % of the leaf area loss was a result of leaf fall, and around 2% directly the result of possum browse. The remaining 3-5 % of leaf area was consumed by insects.

Table 4.1 incorporates leaf growth into the equation to enable the calculation of net leaf area change. Average net growth for one year at both sites was just over 20 %.

Figure 4.3 Mean percent leaf area losses from mistletoe plants

a) Pleasant Flat (n=20)



b) Deer Stalkers Flat (n=20)

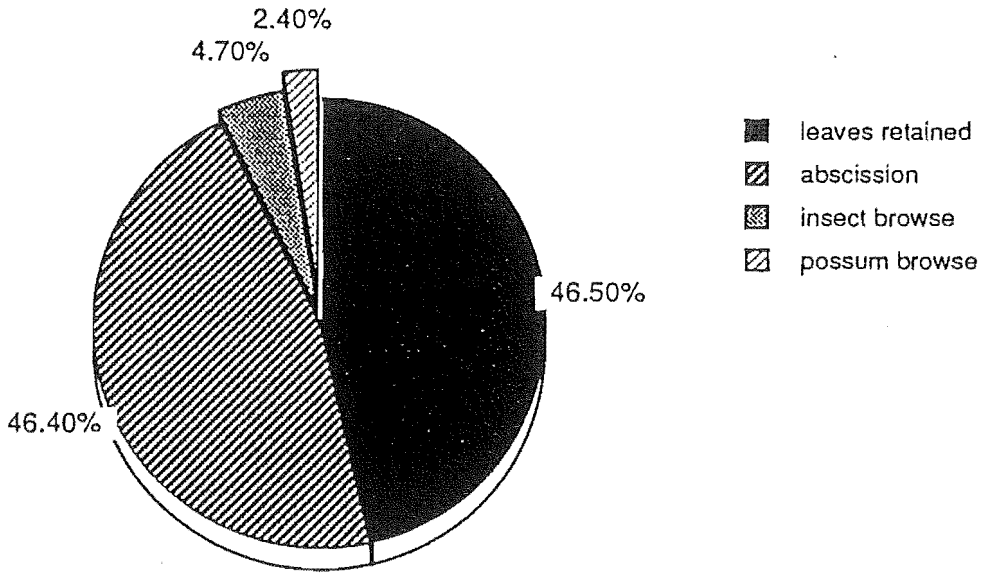


Table 4.1 Breakdown of average mistletoe leaf area change at Pleasant and Deer stalkers Flat monitoring sites.

a)

Pleasant Flat	leaf area (%)
initial leaf area	100.00
possum browse	-1.84
insect browse	-3.40
abscission	-45.05
growth	+72.5
net change	+22.11

b)

Deer Stalkers Flat	leaf area (%)
initial leaf area	100.00
possum browse	-2.40
insect browse	-4.70
abscission	-46.50
growth	+74.4
net change	+19.80

4.5.2 Intensities of browse on individual plants

Possums

Of the 40 mistletoes sampled 7 plants (17.5%) were browsed by possums . Possum browse was recorded on 2 of the 20 P.F plants, and 5 of 20 plants at Deer Stalkers Flat. One plant (P.F 1.) was heavily browsed (26.4 % of leaf area removed, Table 4.2). The remaining 6 plants had moderate or light damage (ie.possum browse removing 5-12 % of leaf area, Table 5.2). The measurement of leaf area consumed by possums is a minimum estimate. It does not include leaves completely removed by browsing possums, or leaves abscissed after browsing.

Insects

In contrast to possum damage, insect browse was more evenly spread over the 40 plants sampled. All plants were browsed by insects, and this browse ranged in intensity from 0.5 % (D.S 2) to 14.3% (D.S 4) (Table 4.2). On average insects consumed 3.4 % of each plants leaf area at Pleasant Flat and 4.7 % at Deer Stalkers Flat (Figure 4.1).

4.5.3 Changes in leaf area: possum browsed and unbrowsed plants

leaf loss

Obviously all plants experienced some loss in leaf area and these losses ranged from 9 % (D.S 20) to 100% (P.F 2, D.S 5) (see appendices A & B). However the average leaf loss of possum browsed plants was higher than that of unbrowsed plants (Table 4.3a). Browsed plants lost an average of 73.4% of their leaf area, unbrowsed plants lost an average of 49.4%. These means were significantly different ($t = 2.81$, $P<0.05$).

leaf growth

There was no significant difference between the mean leaf area growth of possum browsed and unbrowsed plants (table 4.3b, t -1.33. P> 0.20).

The amount of vegetative growth varied considerably amongst both browsed and unbrowsed plants (see appendix A & B). All plants produced some leaf growth except PF 2 which died in February (following the death of its host branch).

Net leaf area

Just under 82 % of unbrowsed plants experienced increases in net leaf area, while only 29 % of the possum browsed plants recorded a net leaf area increase. Possum browsed plants had an average net leaf area change of -8.0%, unbrowsed plants showed an average net leaf area change of +30.5% (Table 4.3c). This difference was significant (t -2.62, P< 0.05).

Table 4.2 Percentage of Mistletoe Leaf Area eaten by possums and insects (*PF 2 data not included, plant died Feb '91).

a) Pleasant Flat

plant no.	Possum browse	Insect browse
PF 1	26.4	3.9
PF 2*	-	-
PF 3	0	1.7
PF 4	0	9.5
PF 5	0	4.8
PF 6	0	1.6
PF 7	0	1.2
PF 8	0	2.5
PF 9	0	0.6
PF 10	0	1.1
PF 11	0	2
PF 12	0	1.9
PF 13	0	3.6
PF 14	0	3.1
PF 15	0	11.5
PF 16	0	3
PF 17	0	1.5
PF 18	11.5	5.1
PF 19	0	1.1
PF 20	0	2.3

b)Deer Stalkers Flat

plant no.	Possum browse	Insect browse
DS 1	5.6	0.5
DS 2	0	3.8
DS 3	9.2	7
DS 4	10.5	14.3
DS 5	0	0.6
DS 6	0	12.1
DS 7	0	5.3
DS 8	0	10
DS 9	0	1.6
DS 10	0	0.7
DS 11	0	1.2
DS 12	0	2.1
DS 13	0	2.9
DS 14	0	5.7
DS 15	0	2.7
DS 16	0	6.3
DS 17	12.1	3.7
DS 18	5.9	7.3
DS 19	0	2.1
DS 20	0	4.2

Table 4.3 Mean changes in leaf area (%), possum browsed and unbrowsed mistletoe plants. (* indicates that $p < 0.05$)

a) Leaf area loss

	N	Mean	Std. error	D.F	T
browsed	7	73.4	7.5	10	2.81*
unbrowsed	33	49.4	4.1	.	.

b) Leaf area growth

	N	Mean	Std. error	D.F	T
browsed	7	65.4	8	17.9	-1.33
unbrowsed	33	79.8	7.3	.	.

c) Net leaf area change

	N	Mean	Std. error	D.F	T
browsed	7	-8	11	17.1	-2.62*
unbrowsed	33	30.5	9.7	.	.

4.5.4 Seasonal patterns of possum browse

The main period of possum browsing occurred over the winter months between May and August. Six of the seven browsed mistletoes were eaten exclusively between May and August. The only plant browsed outside this time interval was Pleasant Flat 1, (Figure 4.4) which had 28% of its browse occur in the February-May period, and the remaining 72%. during the May-August period.

4.5.5 Seasonal leaf loss and growth: browsed and unbrowsed plants

Average seasonal leaf fall and growth for possum browsed and unbrowsed plants is shown in Figure 4.5. The percentage of leaves retained by unbrowsed plants was similar to that of browsed plants between February and May. However through both the May-August and August-November periods, leaf loss was higher from possum browsed plants. By November unbrowsed plants still retained 50 % of their original leaves, whereas browsed plants only retained 34 %. Although both groups produced a similar amount of growth the greater leaf retention of the unbrowsed plants meant they were able to produce a 30 % increase in the number of leaves by November compared to an 11 % increase by browsed plants.

There is a discrepancy between the 11% growth in leaf number quoted here above and the -8.0 % loss in leaf area calculated for browsed plants in section 4.5.3. This is because a proportion of the leaves included in the calculations for percent change in leaf number were browsed leaves, but were still recorded as present (ie. given a value of 1.0). In calculating leaf area, browsed leaves were given values of 0.3, 0.6 or 0.9 (see section 4.4.2).

Figure 4.4 Seasonal patterns of possum browse on the seven mistletoes attacked.

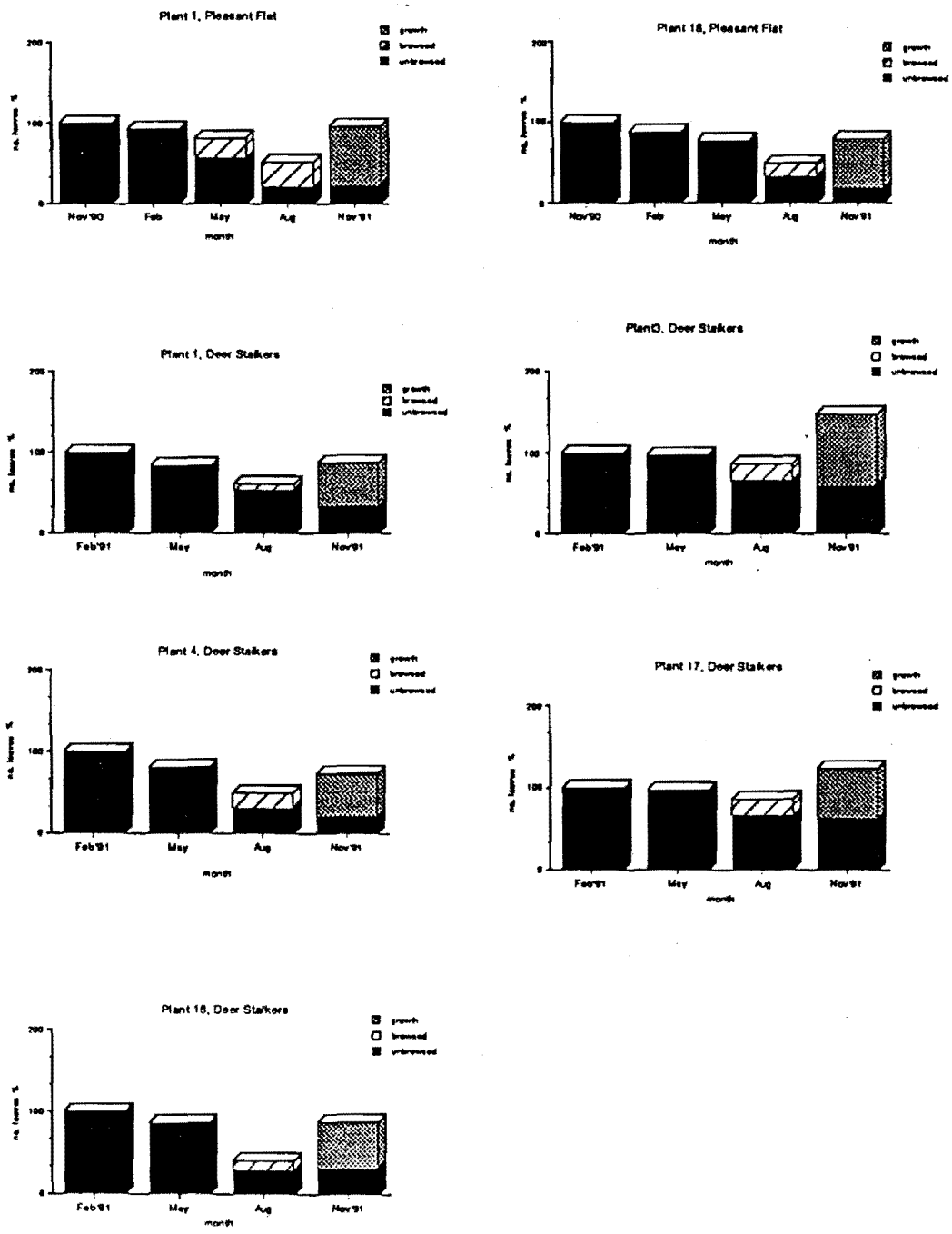
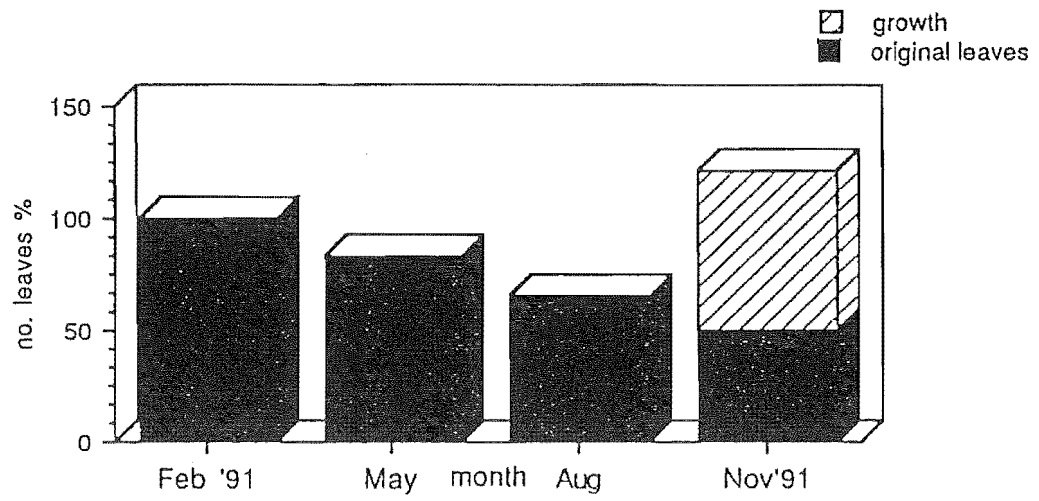
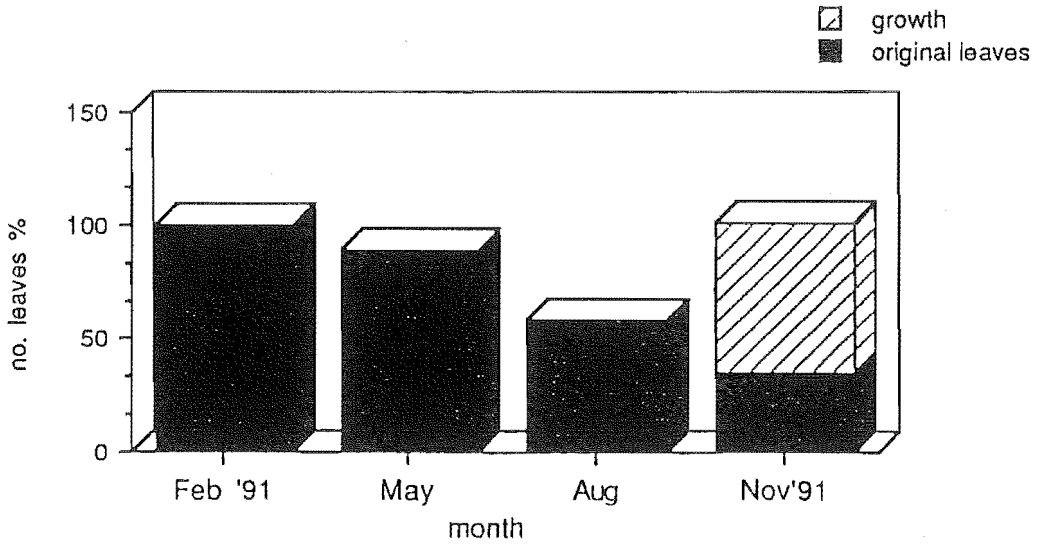


Figure 4.5 Seasonal patterns of leaf fall and growth on possum browsed and unbrowsed mistletoe.

a) Unbrowsed plants (n=33)



b) Possum browsed plants. (n= 7)



4.5.6 Comparing intensity of browse to leaf area change

It has already been shown that on average possum browsed plants lost more foliage than unbrowsed plants (ie. had significantly smaller increases in net leaf area). Regression analysis was carried out on the 7 browsed plants to determine if a relationship existed between the intensity of possum browse and net plant growth (ie. did the most heavily browsed plants produce the lowest net growth). No such relationship was found. For example D.S 4 had half the browsing pressure of P.F 1 but experienced a leaf area loss three times as great. D.S 17 suffered average levels of browse but produced a net change in leaf area over 3 times the sample average. The only observation that can be made is that the most heavily browsed plant (P. F. 1) did suffer the heaviest net leaf loss of the 7 plants.

4.5.7 Phenology

Mistletoe plants produced one growth flush in spring. This growth was from buds carried over winter. Buds broke after August and were fully extended and carried leaves by November. Leaf fall occurred throughout the year (Appendices A & B).

The mistletoe plants monitored at Deer stalkers and Pleasant flat did not flower during the 1990/91 season. However, 15 plants out of 40 had developed flower buds in November 1991 (Appendices A & B).

4.6 Discussion

4.61 Possible sources of sampling bias and error

12 month vs. 9 month monitoring

When the fourteen plants scored in November 1990 were re-scored in February 1991 little change was apparent in their condition. There was no sign of possum damage and light insect browse recorded on a few plants. These observations indicate that the leaf area change and possum browse results would not have significantly altered had data been available November 1990-February 1991 period.

Practical considerations meant the length of each twig sampled had to be limited, this had implications for plant growth estimates. Plant growth calculations were based on the production of new leaves relative to a twigs initial leaf area. Given the number of leaves initially measured on a twig was limited, but, all new leaves were recorded, results may have over estimated growth. Any error however was constant and should not have influenced comparisons of browsed and unbrowsed plants.

The fact that only apical sections of twigs were tagged means there was a sample bias towards younger leaves (mistletoes grow from an apical meristem).

The number of leaves recorded as possum browsed is almost certainly an underestimate of the actual leaves eaten or removed by possums. This is because a proportion of leaves are removed entirely by browsing possums (pers. obs.), and damaged leaves tend to drop earlier than undamaged ones (Meads, 1976). This means some of the leaves recorded as fallen may have been

browsed.

The final major limitation to the interpretation of these results is that they are based on only one years data. This short time-frame makes it difficult to identify trends, and creates the unavoidable risk of collecting and interpreting data from a year which is not average or typical of longer term patterns

4.6.2 Possum impacts on browsed plants

Results showed that as a group possum browsed plants were worse off than unbrowsed plants both in terms of leaf area lost and net changes in leaf area.

The deficit in net leaf area possum browsed plants suffered was not the result of poor spring growth, but rather, a high rate of leaf loss over the autumn and winter period. Comparisons with unbrowsed plants indicate that this leaf loss does coincide with a period of natural leaf fall but rates of foliage loss experienced by browsed plants at this time are far in excess of this "natural" rate.

The discrepancy between the foliage losses of browsed and unbrowsed plants is not explained by the number of browsed leaves alone (on all but one of the plants attacked by possums only termed low to moderate levels of possum browse were recorded). Accepting that some leaves were removed entirely and therefore not recorded as browsed, levels of defoliation suggest that foliage losses suffered by possum browsed plants involve more than those leaves directly ingested.

Leutert (1988) found a strong correlation between the occurrence and intensity of browsing and foliage loss on rata trees. There appears to be a similar relationship in mistletoe plants. It is not possible to estimate what proportion

of leaves are damaged by possums and prematurely abscise but presumably it is considerable. It is also likely that possums climbing in mistletoe break and damage a proportion of the plants branches.

Possum browsing effectively reduces the photosynthetic area of a plant, which can lead to increases in physiological stress which may in turn cause an increase in the rate of foliage loss (Payton, 1983). Taken to its extreme, possum related defoliation and its associated imbalancing of the plants non photosynthetic to photosynthetic tissue ratios will result in plant death (Payton, 1983).

Seasonal browsing and leaf preferences

Possums browsed mistletoe almost exclusively between the winter months of May and August. By August the physical characteristics of the present and past seasons leaves were similar so that there was no clear distinction between "young" and "old" leaves It was difficult to determine leaf age without counting annual scars on twigs. Possums, by browsing in winter, appeared not selectively browse new foliage.

Evidence that possums had browsed plants at a similar time the previous year was provided by observations of old possum damage.. when mistletoe plants were initially tagged. Possum browse was present on three plants (P.F 1, Nov'90; D.S 3 and D.S 4, Feb'91). This damage occurred only on older leaves, and was not evident on any of the leaves produced that had been produced in the spring (see Plate 1). It appears that possums had browsed the plants over the winter of 1990 prior to spring leaf expansion.

Winter browsing may be a behavioural response to variation in the palatability of mistletoe leaves with age. If this is the case it makes sense for possums to

concentrate their feeding at a time when the ratio of "young" leaves to "old" is at its lowest. This ratio would probably be at its lowest in late winter prior to spring shoot extension and leaf growth.

Alternatively winter browsing of mistletoe may not be based on positive avoidance of new mistletoe leaves but rather an attraction to competing food sources at a time when fresh mistletoe growth is available. Over spring and summer many highly preferred foods are abundant in the forest, (see Chapter Five, Possum Diet). In response possums concentrate their feeding on these preferred food species. Over winter months the animals tend to eat a different and often a wider range of species. It may be at this time that mistletoe becomes a target for browsing possums.

What influence mistletoe flowering and fruiting or rather the lack of it had on the feeding patterns of possums in the study area is unknown. Mistletoe flowers are an important nectar source for birds during late summer and their fleshy fruit is also a valuable winter food (O'Donnel & Dilks, 1986). Possums avidly consume the fleshy fruits of most plants when they are available and also eat the flowers of many native trees (Cowan, 1990). There is little reason to suspect possums would not take advantage of mistletoe flowers and fruit when they are available. Wilson, (1984) suggests that mistletoe flowers are eaten by possums in the Nelson lakes area.

4.63 Defoliation and growth

A feature of the results was the lack of influence possum browse appeared to have on spring leaf production.

Payton (1983) found that the timing of defoliation was critical in a study of its affects on southern rata (*Metrosideros umbellata*). When defoliation followed

immediately after bud break, ie. in a period of active, growth over the entire branch died. When defoliation occurred after the cessation of growth the over wintering buds survived, and the twig produced produced leaves. Payton suggests the retention of leaves in the period following bud break is critical to allow the build up of sufficient carbohydrate reserves for the survival of the branch or tree.

These findings may explain how heavily defoliated mistletoe plants were able to survive and produce spring growth. It is possible that because browsing was concentrated in winter months and (plants were not defoliated in spring or summer) enough leaf area was maintained at the critical time to enable the successful development of buds.

Selective feeding

It is well established that selective feeding is a behaviour inherently common to brushtail possums (Green, 1984). This selective behaviour involves both the choice of species that constitute diet (eg. Fitzgerald, 1976) and preferences for certain individuals of that food species (eg. Meads, 1976). The selective browsing of a relatively small proportion of mistletoe plants in this study is no exception to this general pattern.

Possums heavily browsed individual mistletoes while plants in adjacent trees were left untouched. Such selective feeding seems likely to increase the potential damage any given number of browsing possums may cause. This is best illustrated by the contrasting impacts of insect and possum browse. On average insects removed a slightly greater mistletoe leaf area than possums, but spread this browse more or less evenly over the 40 plants sampled (with no apparent ill effect). In contrast possums concentrated their browsing efforts on just 7 plants, and these plants suffered a significant reduction in the leaf area.

Relating browsing intensity to plant vigour?

An hypothesis was tested that amongst the seven browsed plants, the intensity of possum browse would be inversely correlated to plant vigour. However when the two variables (% leaves browsed and net leaf area change) were analysed there was little evidence of a relationship.

A possible explanation for this is that the techniques used to measure leaf area change and browse were not sensitive enough to detect changes on the level at which they were occurring, however, it is more likely that one years data is not sufficient to detect a relationship.

It must also be noted that various factors besides possums operate within the environment to effect mistletoe health (for example, host vigour and insect browse). Given the general low intensity of possum browse it seems likely other factors are interacting with and even overriding the effects of possums. Variations in the vigour of mistletoes untouched by possums only need to be considered to illustrate that mistletoe plants fall into decline and die irrespective of the feeding activity of possums. The only plant which died during this study did so of causes unrelated to possums.

4.7 Conclusions

Possums appear responsible for only a minor proportion of total leaf area loss, with a relatively small percentage of plants attacked by possums.

Indications are however that possum browsing does have an impact on the plants attacked. By the end of the monitoring period the leaf area retained by possum browsed plants was significantly lower than unbrowsed plants.

Among the plants attacked by possums the intensity of browse varies, and only a small proportion of plants are heavily browsed. This selective feeding behaviour means a majority of the mistletoe population are not being browsed at any one time, but increases the intensity and rate of defoliation on the plants possums are selecting.

CHAPTER FIVE

Possum Diet Study

Chapter outline: In this chapter the main techniques used to assess herbivore diet and food availability are critically reviewed. The aims of the diet study and the rational for study site selection are outlined. Methods used to collect and analyse stomachs and assess forage availability are described. Results of possum diet analysis are presented and discussed in terms of their likely impact on mistletoe and other plant species in the study area.

5.1 Introduction

Knowledge of what plant species possums eat, and when, helps scientists and managers predict possum impacts on forest ecosystems, and develope strategies to the protect flora and fauna at risk. There has been a considerable amount of research on the dietary patterns of the brushtailed possum in New Zealands indigineous forests (for example,.Mason,1958; Fitzgerald, 1976; Leathwick, *et al.*,1983; Coleman *et al.*, 1985). These studies have provided valuable information on the feeding behaviour of possums in various habitats, they have also shown there is sufficient regional variation in browsing pressure to upset most generalizations about preferred species. At present there is no quantitative information on possum diet patterns within South Westlands beech forests. There are also no published reports within New Zealand recording. the presence of mistletoe in possum diet (although most diet studies have been undertaken in areas where the plant is rare or absent). In the upper Haast cathcment there is an oppportunity to study

possum diet in an area where possum populations have not yet peaked and mistletoe is still abundant. By relating information on the quantity of mistletoe and other species occurring in possum diet and in the environmet, a better understanding of the possum-mistletoe relationship may be gained.

5.1.1 Study aims

This study was undertaken in conjunction with work directly measuring possum browse on mistletoe plants (see chapter 4). The diet study's broad aim was to gain information on the dietary patterns of the animals living around in the mistletoe monitoring sites. More specifically the objectives were to:

1) Quantify the contribution of mistletoe to possum diet over 12 months by means of quarterly samples and relate this information to the results of the mistletoe browse study.

2) Quantify the proportion of each food type/plant species in the total food intake of the possum population for each quarter.

3, By means of a vegetation survey compare what is eaten to what is available and formulate a list of preferred species.

5.2 Study area and site selection

Location

The diet study area was located in the upper Haast river catchment (see Figure 2.1), its general location and physical description are also covered in Chapter two.

Site selection

Three basic criteria were applied in selecting the specific sites in which gut sampling would take place:

1) Present possum densities and past histories of possum occupation should be similar to the sites at which the mistletoe browse study was undertaken.

2) The removal of possums for gut sampling should not influence possum populations in the mistletoe tagging areas, ie. there must be adequate geographic separation of the populations

3) Any gut sampling area should be floristically similar, (ie. supporting a forest type of comparable age and structure) to that in which the mistletoe browse was being monitored.

With respect to these criteria two suitable sites were identified (Figure 4.1). Both were on alluvial terraces on the true left bank of the Haast River. The Moa Creek site was 2 km. from the Pleasant Flat tagging area and separated by two streams. The second site was slightly closer to the tagging area but a large stream (Baker Creek) effectively separated the Pleasant Flat and Baker Creek possum populations (streams if sufficient in size are barriers to possum movement, I.L. James pers comm.). Surface age, forest structure and species composition in the Baker and Moa Creek gut collecting areas were very similar to those of the tagging areas.

5.3 Review of methods

5.3.1 Diet assessment

Many techniques have been used to assess the diet of herbivores in the past; these include direct observation (watching feeding animals and noting the species eaten) (Pahl 1987), vegetation surveys before-and-after grazing, examination of material from fistulated animals and feeding on a free choice basis (Barker,1986). The fact that possums are small nocturnal, arboreal animals often living and feeding in a complex forest habitat generally negates the usefulness of techniques such as direct observation and before-and-after vegetation surveys.

In New Zealand, analysis of gut and faecal contents have been used to assess deer and possum diet (Nugent,1983). Faecal analysis has generally been the more common method employed (eg. Dunnet *et al.* 1973; Fitzgerald,1976; Coleman *et al,* 1985). The popularity of faecal analysis may be due to the ease of sampling. Pellets are more easily collected in large numbers from a populations entire range than rumen/stomach samples (Nugent,1983). In New Zealand previous assessments of possum diet (eg. Fitzgerald,1976, Coleman,*et al.* 1985) have coincided with possum population studies making it impractical to work with gut samples from dead animals. In Australia sacrificing individuals of a protected indigenous species such as the brush-tailed possum to gain gut samples is not appropriate

Some workers have analysed possum stomach contents (eg Mason, 1958; Gilmore, 1967; Purchas, 1975). Nugent (1983) suggested that macroscopically sampling stomach contents is a superior technique to microscopic faecal analysis, based on the following observations;

- Potential bias due to differential digestion would appear to be greater in faecal analysis (faecal material has a longer passage time in the gut)

- Dry weight composition estimates are more accurate when directly measured as is done in macroscopic analysis than when calculated from relative surface area and correction factors as is the procedure in microscopic analysis of faecal material (Dunnet *et al.*,1973).

- Plant species are more uniformily and accurately identifiable using macroscopic features. The proportion of unidentifiable material is generally less than the 10-30% of unidentified epidermal fragments common in microscopic analysis.

-For the purposes of this study the ease of sampling faecal pellets appears to be outweighed by the greater potential biases.

Methods of macroscopic analysis

Two techniques are commonly used in macroscopic gut analysis; sorting and point sampling. Nugent (1983) critically assessed the merits of both techniques. Point analysis is a quick but approximate method useful for determining the three or four most common species eaten. Sorting provides a more precise estimate of the relative proportions of all species in the diet; it was deemed the more appropriate technique the purposes of this study.

Indices of digestion

The physical and chemical structure of each plant species will affect the rate at which its tissue is broken down by a herbivore's digestive system. Digestion indices are used to 'correct' raw data biased by the differential rates of digestion. They have their most important application in faecal analysis where material analysed has been digested to the fullest extent (eg. Fitzgerald, 1976).

Dunnet *et al.* (1973) carried out feeding trials with captive possums to compare the proportions of different plant species fed to animals with those identified in faeces. By analysing these data Dunnet produced an index of digestion for various plant species.

Given the time involved in setting up feeding trials and the fact that stomach and not faecal samples were analysed here, indices were not calculated in this study. It should therefore be noted that softer tissue (eg. fruit) which is generally more digestable than leaves (Williams, 1982) may be underestimated in dry weight measurements

5.3.2 Estimating food availability

Diet estimation is only part of the information required to predict the impact of possums on their habitat. To establish which are preferred or potentially vulnerable species estimates of plant availability are required.

Different workers have used a variety of techniques to assess the proportion of plant species available to herbivores. A lack of conformity in methodology amongst workers probably reflects the diverse habitats and feeding patterns of herbivores studied. Ideally an assessment of availability should be expressed in terms of proportion of edible biomass; measured and recorded in the same units used to estimate diet eg. % dry leaf weight (gm).

McAlister & Borman (1972) sampled vegetation of impala (*Aepyceros melampus*) territories by estimating leaf cover and transforming proportions of species by cover to proportions by dry weight. Nugent (1990) assessed the proportions of forage available to fallow deer in the Blue Mountains. All potentially edible material within 1.5 m of the ground in 184 1.14 m radius plots was harvested by hand and dry weighed. Parkes (1987) used a less destructive technique to the estimate forage available to feral goats. At 200 sites he recorded the number of times edible parts of species touched a 1.25 m vertical rod held in five positions.

Techniques used to assess the proportions of plant material available to ground-dwelling ungulates are not easily adapted to assess what is available to arboreal possums. Possums' ability to climb and feed in every strata of the forest means that a destructive and expensive harvesting technique must be used if proportions of edible biomass are to be directly measured in units of dry weight. For example, Beets (1980),.estimated biomass by harvesting a representative sample of the main vegetation types in a mature beech/podocarp forest about to be logged. Obviously a less destructive technique is needed on the conservation estate

During a study of the common ringtail possum Pahl (1987) calculated canopy cover of species in *Eucalyptus* plantation/semi-natural forest. Canopy radii of individual trees were estimated and used to calculate species canopy areas. Making similar measurements in often tall and complex New Zealand forests would be more difficult, and also ignores other species.

Mason (1958) studying Orongorongo Valley possums compared stomach contents to lists of plant species growing close to the trap in which each animal was caught. Such lists give an indication of forest composition but do not

allow a comparison of what is eaten with what is available. More recently, standard forest inventory methods have been adapted for the purpose of quantifying species availability or abundance. Park (1973) refined and Leathwick et.al (1983) used the point height intercept (P.H.I.) method to estimate species composition in three North Island forests. P.H.I. involves recording the frequency of vegetation intercepts along a vertical sight-line taken at random points. In tall dense forest there is an acknowledged problem in establishing a vertical line from a point with no horizontal dimensions (Spurr & Warburton, 1991).

Spurr and Warburton (1991) compare estimates given by three standard forest inventory methods, stem density, basal area and vegetation cover (Allen and Mclennan, 1983) with their own measure of vegetation surface area (modified from Park, 1973). They recommended using vegetation surface area (which includes trunks, branches and foliage) to assess bird habitat, but noted that vegetation cover gave a good estimate of foliage surface area alone. Given the difficulties of making quick and accurate measurements of plant biomass within forest a simple technique such as vegetation cover can provides a useful estimate and was considered the most suitable technique for the purposes of this study.

5.3.3 Plant preference ratings

Preference ratings are a way of expressing the relationship between plant utilisation and availability. Ratings are based on the differences between the animals proportional use of a plant and the proportion of that plant in the habitat.

Negative selection or preference occurs if the intake of a food item is less than the quantity in the environment. Preferences are neutral when use equals

availability and positive selection occurs when use is greater than availability (Jacobs, 1974).

5.4 Methods

5.4.1 Field and laboratory methods

Gut collection

A minimum sample of 20 possums were collected each quarter using potassium cyanide poisoned baits. The poisoning procedure was as follows:

At 10-15 m. intervals a pre-feed lure (flour/curry mixture) was laid at a site likely to attract possums. The lure was left for two fine nights, on the third night potassium cyanide baits were laid. If kills were not high enough after the first poisoning baits were laid again the following night. Approximately 100 baits were laid at Baker Creek and 50 baits at Moa Creek per poisoning night. Each animal had its sex and colour recorded and was classified as mature or juvenile on the basis of testes or pouch development. A subjective assessment of animal condition was made by using the relative depth of fat on the back and hips as an indicator of possum condition. Animals were classed as being in poor, average or good health.

Gut analysis

Each possum stomach was removed whole and frozen as soon as practicably possible. Methods were based on the procedures outlined for macroscopic gut analysis by Nugent (1983). Possum stomachs were individually thawed then rinsed over a 2 mm sieve to remove plant fragments to difficult to handle and identify. The remaining sieved digesta was blotted on tissue paper and 5 ml.

measured by water displacement. The ingested material generally retained the natural colour and characteristics of fresh foliage and could be sorted into appropriate species or food type groups when viewed through a magnifying lens. Identifications were checked by comparing plant fragments from stomachs with herbarium specimens. If doubt persisted plant cuticle samples were examined under microscope and compared to reference slides. In most cases identifications were made to the species level, a few species were difficult to distinguish and were combined into a genus group, for example *Rubus* and *Coprosma* spp. Each species or food type was oven dried for 48 hours at 85° C. then weighed.

Assessment of forage availability

In early November the relative cover of plant species was estimated in the gut sampling areas. One hundred plots were located on a transect following the Baker creek poison line. A further fifty plots were located along the Moa creek line. Plot centres were spaced at 10 m intervals. Within a 2m radius of each plot centre the percent foliage cover of each plant species was determined in four height tiers (Table 5.1).

The percent cover of a plant was estimated as the proportion of plot area covered by a downward vertical projection of its foliage. Separate estimates were made in each height tier.

Percentage cover scores are a 2-dimensional estimate of relative cover abundance. As a result species with greater foliage depth or occurring in larger height intervals tend to be under estimated. To compensate for this, percentage cover scores in each tier can be weighted by their relative tier height intervals (Spurr and Warburton,1991). The weighting system and height tiers adopted in this study are based on those of Park (1973) who scored and weighted four

height tiers to quantify floristic parameters in silver beech forest similar in structure to the Pleasant Flat stands.

5.4.2 Data analysis

Calculating mean %.dry weight from gut samples

Mean percentage dry weights for each species/food group were calculated by dividing species dry weight with total dry weight for all gut samples taken in a season. Species dry weights were the sum of all dry weights recorded for that species in a season. Total dry weight was the sum dry weight of all gut samples taken in a season.

Calculating mean % availability

To enable a preference index to be calculated for each plant species overall percent cover values were calculated for each plant species This was done by summing appropriately weighted % cover scores (see Table 5.1) for all tiers in all plots. The proportion each species contributed to total vegetation cover value was then calculated. If species were recorded in vegetation plots which were unable to be distinguished in stomach analysis they were combined into a single plant group.

Table 5.1 Plot height tier intervals and weights used to assess plant cover in gut sampling areas.

Tier	Height interval (m)	Weight
ground	0.0-0.3	0.25
shrub	0.3-2.0	1.25
subcanopy	2.0-6.0	1.5
canopy	6.0+	1.5

Assessing food preferences

Food preferences were assessed using a methodology similar to that of Nugent (1990). A simple formula is used to calculate preference indices (P.I), where,

P.I= (% in diet-% available)/(% in diet+% available).

This formula produces P.I values distributed symmetrically about zero. Ranging from -1(present in plots absent in stomachs) to +1 (present in stomachs absent in plots). P.I values were calculated for each of the plant species/groups occuring in the November stomach samples.

ANOVA of seasonal changes in diet

Seasonal differences in the mean % dry weights of the ten most commonly eaten food items were evaluated by analysis of variance and Duncans Multiple Range Test. The foods compared were, wineberry, pohuehue, larvae, lawyer, fuchsia, *Pseudopanax* spp., rohutu, fruit, kaikomoko, and silver beech.

The statistical procedure described above was also used to analyse the variation in the average number of species eaten in each season (sampling month)

5.5 Results

5.5.1 Important foods in possum diet

A total of 35 different species or food groups were identified in the 81 gut samples analysed. Of these 23 contributed over 1% of diet in a single month (Table 5.2).

The extent to which overall diet is dominated by just a few species is illustrated

when the contributions of the ten most important food items are compared (Figure 5.1). Two species, wineberry and pohuehue contribute 55.8% of annual diet. The four largest food items (wineberry, pohuehue, larvae and lawyer) make up 68.4% of annual food intake, the next six food items contribute just 18 %.

The four most important plant foods were the leaves of wineberry, pohuehue, rubus, and fuchsia (Table 5.2). The leaves of *Pseudopanax* spp (3.6%), rohutu (2.7%) and *Coprosma* spp.(2.5%) were eaten in smaller amounts.

Invertebrate larvae (Dipteran species) (P Walsh, pers comm.) were an imporant food source making the third largest contribution to annual diet (7.6% of annual dry weight, Figure 5.1)

Fruit formed only 2.5% of annual diet in terms of dry weight. If diet had been measured in mean percent volumes, its contribution would have no doubt been larger. Fruit has a higher water:volume ratio than other food types, (for example, leaves) which means the dry weight analysis procedure may have negatively biased its contribution.

Figure 5.1 Annual contribution to possum diet of ten most important food items (mean % dry weight).

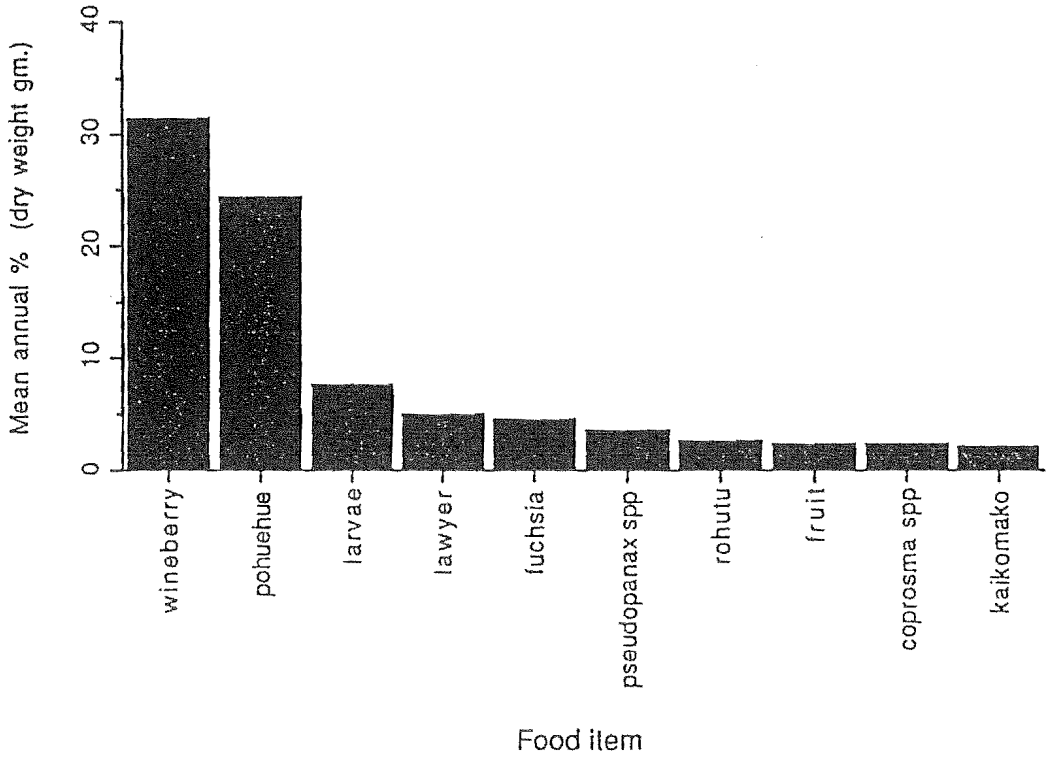


Table 5.2 Mean % dry weights of food items contributing >1% to possum diet in any one month.

Food item	FEB	MAY	AUG	NOV	AVE
wineberry	36.3	38.4	37.6	13.2	31.4
pohuehue	31.9	16.4	0.3	49.1	24.4
larvae	0	2.1	28.1	0	7.6
lawyer	0.8	0.8	2.7	15.5	5
fuchsia	7.6	0	0	10.2	4.5
Pseudopanax spp	0.9	4.5	8.3	0.5	3.6
rohutu	0	8.6	2.1	0.2	2.7
fruit	9.5	0.3	0	0	2.5
Coprosma spp	5.7	1.2	2.6	0.3	2.5
kaikomako	0	8.8	0	0	2.2
sheld fern	2.3	2.3	3.2	0.7	2.1
kamahi	0.3	4.1	3.8	0	2
grass	0.5	2.1	3.9	0.6	1.8
silver beech	0.1	3	2.3	0.6	1.5
Blechnum spp	0	0	0	4.1	1
pate	0	3	0.4	0	0.9
Asplenium spp	0.1	0.2	0	3	0.8
herb spp	0	2.1	0	0.5	0.6
bark	0.9	0	1.4	0	0.6
seed	1.7	0.1	0.1	0	0.5
pirita	0.3	0	0.1	1.4	0.5
mahoe	0	0	2	0	0.5
Myrsine divaricata	0	1.7	0	0	0.4

5.5.2 Seasonal variation in diet

Seasonal changes in commonly eaten food types

Consumption of nine out of the ten most popular food types varied signifigantly between seasons. In four of the ten species analysed seasonal variation was highly signifigant (P<0.001, Table 5.3), fruit was the only food not to show significant seasonal differences.

Large (Figure 5.2a, 5.2b, 5.2c.), and not significantly different amounts of wineberry were eaten in February May and August. In November the quantity of wineberry eaten was significantly less than in the other three months (Figure 5.3).

The amount of pohuehue eaten differed significantly in all months (P>0.001; Table 5.3, Figure 5.3). Largest amounts of pohuehue were eaten in November when it was the dominant food item in 67% of samples. Progressively smaller amounts were eaten in February, May, and August.

Invertebrate larvae formed a large part of possum diet in August (Figure 5.3c) significantly greater than in February May and November (P< 0.001, Table 5.3, Figure 5.3).

Small and not significantly different amounts of lawyer were eaten in May, February and August (Figure 5.3). Lawyer did however provide 15.5% of diet in November (Figure 5.2d). This seasonal increase in consumption was signifigant (P<0.001, Table 5.3).

Fuchsia was an important food item in November and February (Figures 5.2a & 5.2d) but was not present in guts sampled in May or August.(Figures 5.2b &

5.2c). The difference between consumption levels in February and November was not signifigant nor were the differences between May, August, and February. The amount eaten in November was significantly higher than the May or August levels (Figure 5.3).

The proportion of *Pseudopanax* spp. eaten was largest in August (Figure 5.2c) and significantly higher than amounts eaten in November and February. The differences between May and August were not significant (Figure 5.3).

In May gut samples rohutu ($P<0.05$) and kaikomoko ($P<0.01$) was present in significantly higher amounts than in the other three sampling periods. Consumption levels in other months were low and not significantly different in either species (Figure 5.3).

Fruit contributed 9.6% of diet in February and in terms of total dry weight was the third most important food item eaten in that month. Small amounts of fuchsia fruit were found in two gut samples taken in May. Fruit was not present in August or November samples. There was considerable variation in the amount of fruit contained in February gut samples, animals tending either to have large amounts of fruit in their stomach or none. As a consequence of this variability within the February sample, seasonal differences were not signifigant (Table 5.3).

Small amounts of silver beech were consistently present in all four seasonal samples. Silver beech's contributions to diet in May was significantly higher than that of February or November but not different from that of August (Figure 5.3). Differences were significant at the 0.05 level only (Table 5.3).

Seasonal variation in the number of foods eaten

There was a signifigant difference in the mean number of foods eaten by possums in 3 out of 4 sampling months ($P<0.001$, Table 5.4).

The mean number of species eaten in May was 6.5, significantly higher than in other months. The average number of different foods consumed in August was 5.6 and in November 5.2 (Figure 5.4). In February diet was least diverse with only 4.2 food items on average found in each gut sample.

Table 5.3 Analysis of Variance: seasonal contributions to diet of the ten most common (% frequecy of occurence in gut samples) food items. (n.s=not ignificant).

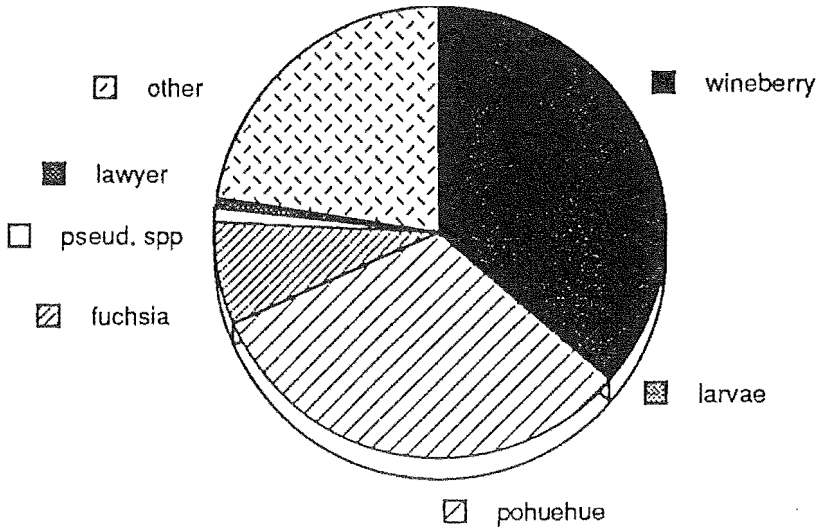
Food item	F	P
wineberry	4.1	<.01
pohuehue	18.7	<.001
larvae	15.5	<.001
lawyer	6.2	<.01
fuchsia	4.3	<.01
Pseodopanax spp.	5.5	<.01
rohutu	2.9	<.05
fruit	1.2	n.s
kaikomako	7.3	<.001
silver beech	2.9	<.05

Table 5.4 Analysis of variance: number of food types present in each seasonal sample.

	F	P
foods/gut /season.	9.5	<.001

Figure 5.2 Seasonal diet patterns of six most important food items (mean annual % dry weight).

a) February (n=20 gut samples)



b) May (n=20 gut samples)

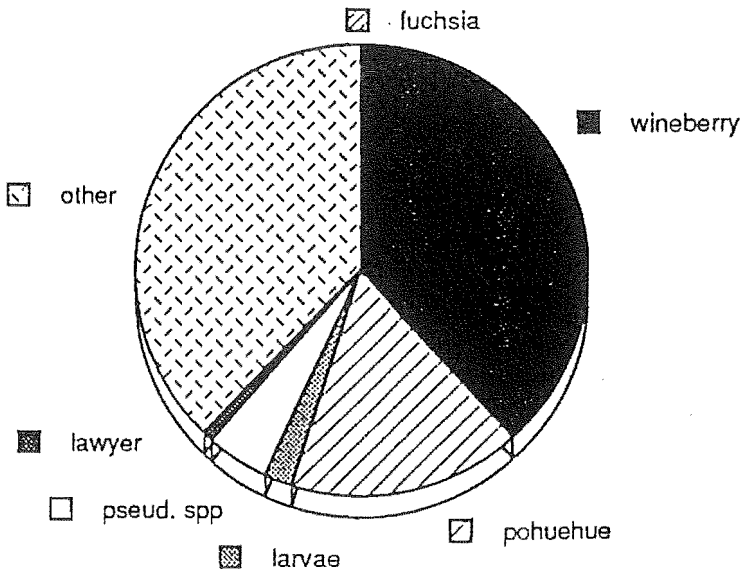
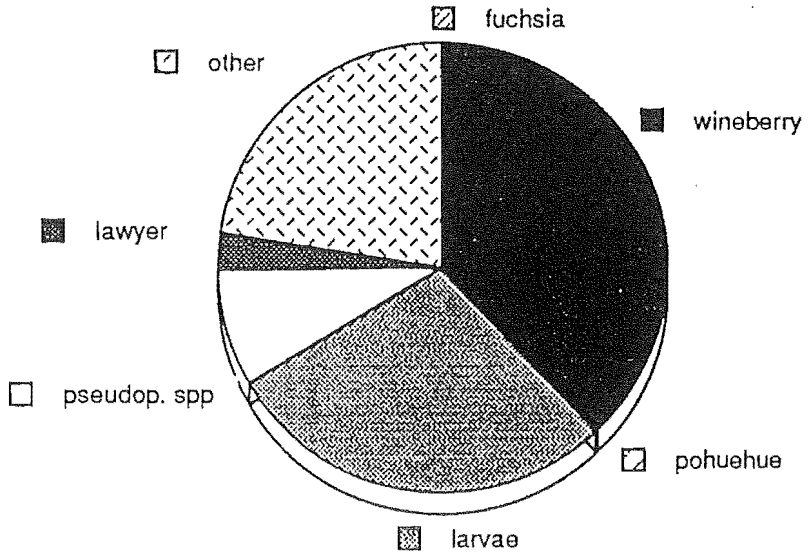


Figure 5.2 (cont.)

c) August (n=20 gut samples)



d) November (n=21 gut samples)

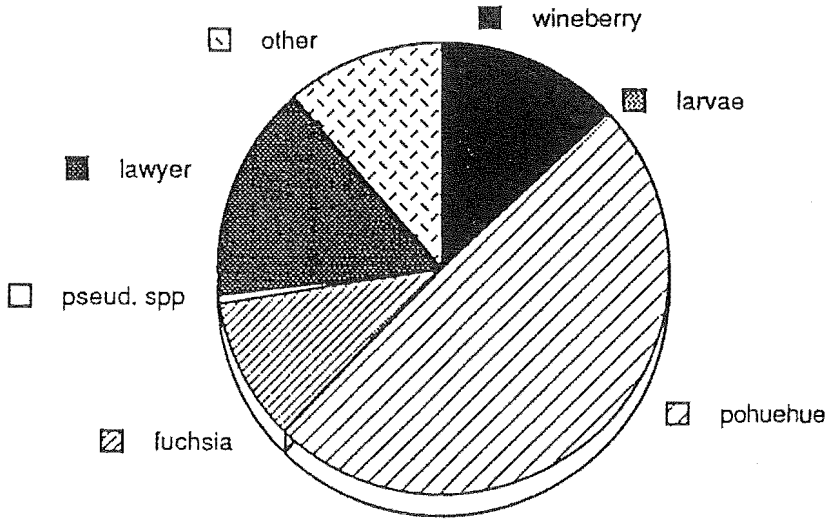


Figure 5.3 Mean monthly contributions to diet of ten most commonly eaten food groups. (analysis of variance carried out on dry weight, gm). Values not joined by a continous line are significantly different ($P<0.05$).

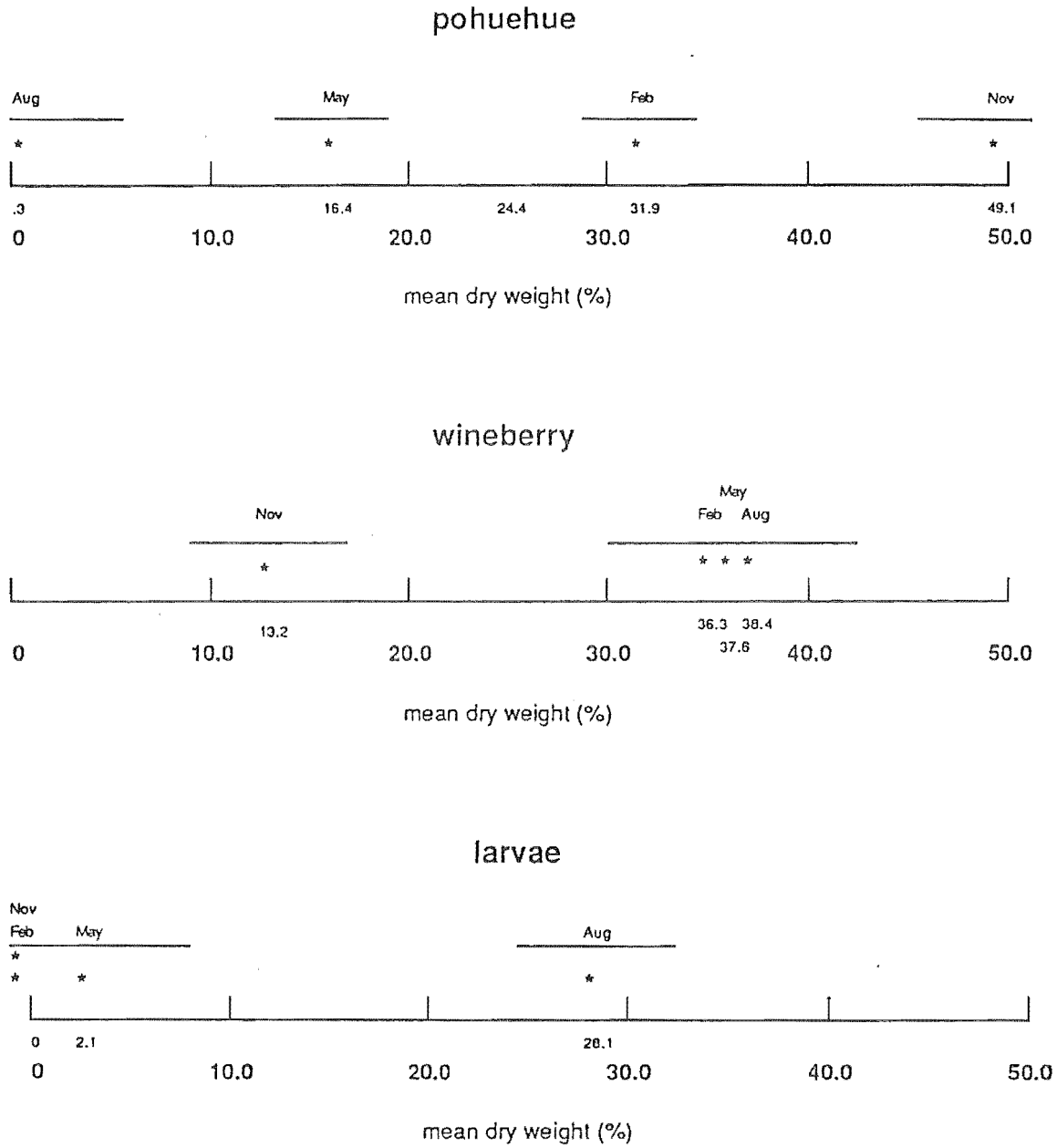
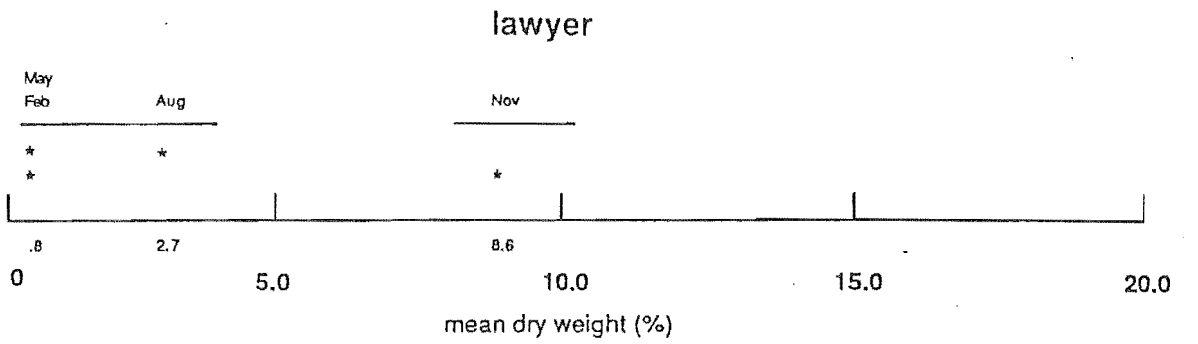
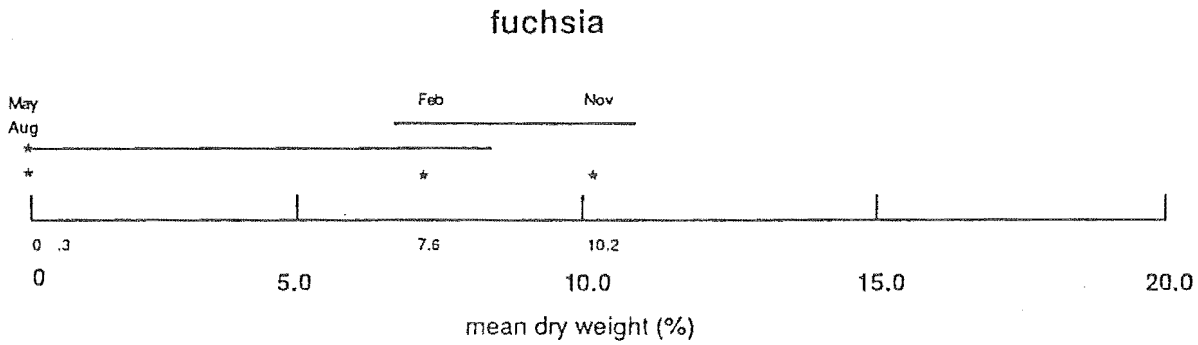
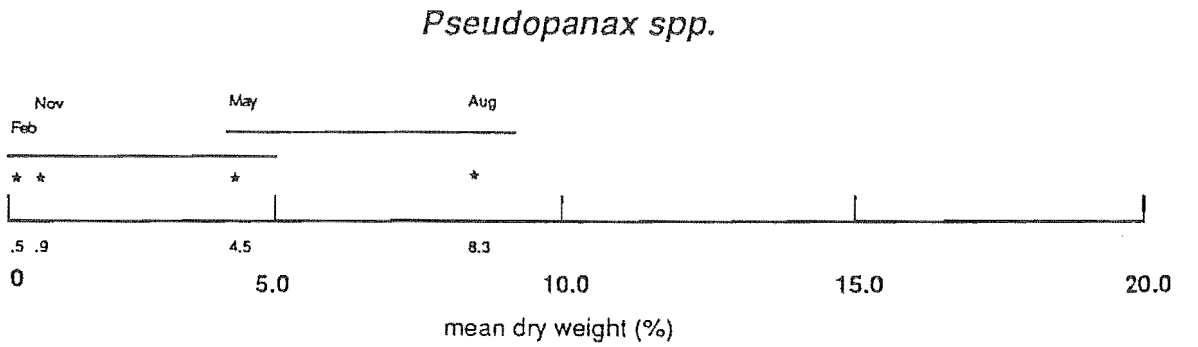


Figure 5.3 (cont.)







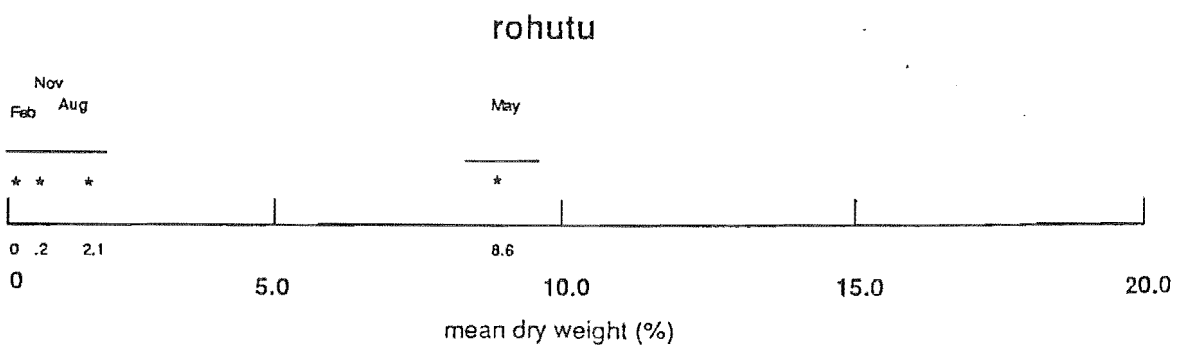


Figure 5.3 (cont.)

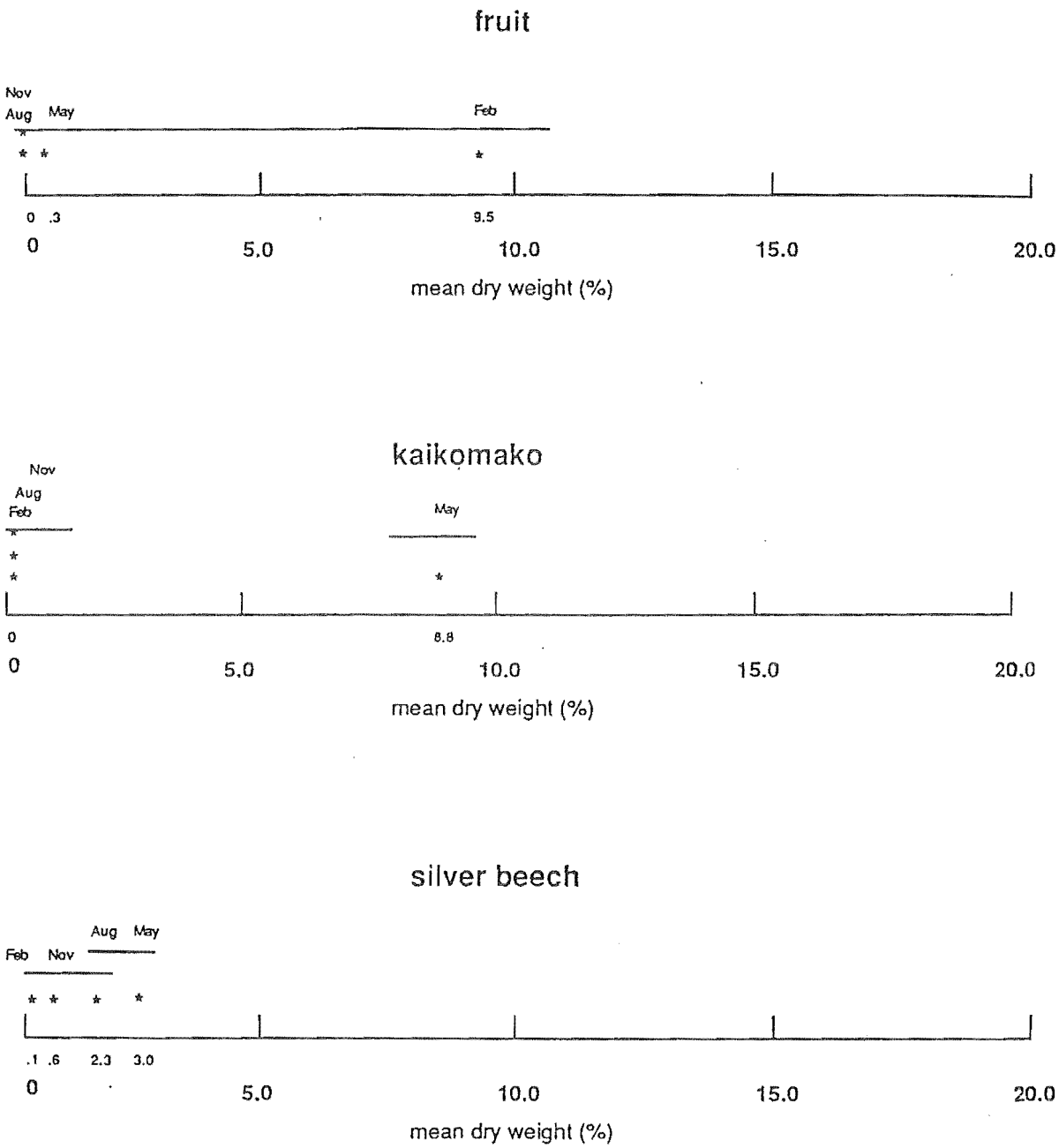
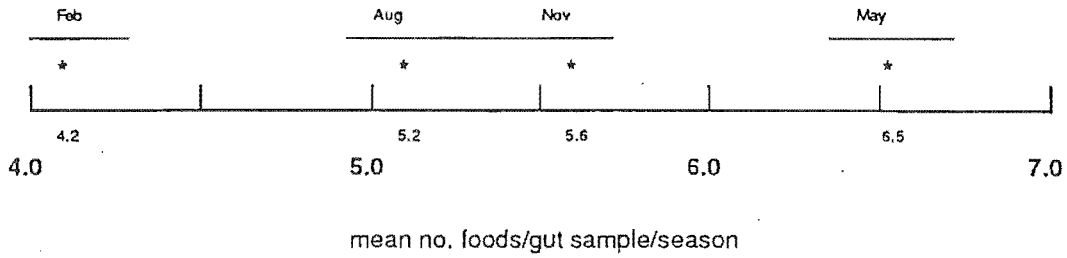


Figure 5.4 Seasonal variation in the number of food items eaten. Values not joined by a continous line are significantly diiferent (P<0.05).



5.5.3 Plant Availability

Mean % cover values are shown in Table 4.5. These are estimates of green biomass availability.

As expected silver beech, the dominant species in the forest, had the highest total cover of 47.8% (Table 5.5), over half of the subcanopy tier and over 90% of the canopy. Six species had cover values between 3% and 9%, with the remaining 26 plant species/groups contributing just 22% of foliage (Table 5.5).

After silver beech the two most important species were the *Coprosma's* and horopito contributing 8.5% and 6.6% of foliage biomass respectively. Rohutu (3.2%) and *Pseudopanax* spp. (2.0%) were also relatively important components of the shrub and sub-canopy tiers. Shield fern often formed a dense cover in ground and shrub tiers and provided the third largest contribution to foliage biomass (5.2%). Bryophytes covered nearly 60% of the forest floor and its total contribution to green biomass was estimated as 4.3%. Ferns, especially shield fern (*Polystichum vestitum*) and herbs (mainly *Nertera dichondraefolia*) were relatively common on the forest floor, grass contributed only 0.2% of green biomass.

The four most important plant species in possum diet, wineberry, pohuehue, lawyer, and fuchsia had availabilities ranging from 2.4% (wineberry) to 0.6% (fuchsia).

Table 5.5 Proportions of leaf biomass within each height tier (% cover values).

Species	ground	shrub	sub-canopy	canopy	mean %
silver beech	1.2	6.1	55.4	92.7	47.8
Coprosma spp	1.1	20.5	6.3	0	8.5
horopito	1.4	14.7	6.6	0	6.6
shield fern	9.9	13.5	0	0	5.2
Bryophytes	56.9	0	0	0	4.3
Cyathea smithii	0.3	9.9	0.1	0	3.3
rohutu	0.2	7.8	2.3	0	3.2
wineberry	0.1	3.2	5.3	0	2.4
Pseudopanax spp.	1.6	5	1.3	0	2
broadleaf	0.1	1.2	5.3	0	1.7
ribbonwood	0.2	0.4	2.8	2.2	1.6
miro	0.1	0.2	0.3	3.9	1.5
ferns (other)	5.1	2	0	0	1.3
kamahi	0	1.2	3.3	0	1.2
poehuehue	0.5	2.1	1.9	0	1.2
kaikomako	0.2	0.8	3.3	0	1.1
Hails totara	0	1.3	0.7	0.9	0.9
pate	0.3	2	0.8	0	0.8
Blechnum spp.	5.3	0.9	0	0	0.7
lawyer	0.8	1	0.9	0	0.6
fuchsia	0.2	1.4	0.5	0	0.6
Asplenium spp.	4.5	0.8	0	0	0.6
Myrsine divaricata	0.3	1.5	0.3	0	0.6
putaputaweta	0	0.6	1.3	0	0.5
herb spp.	6.6	0	0	0	0.5
Dicksonia squarrosa	0	1	0	0	0.3
Parsonsia capsularis	0.1	0.5	0.7	0	0.3
pirita	0	0	0.6	0.4	0.3
grass spp.	2.6	0	0	0	0.2
kahikatea	0.2	0.4	0	0	0.2
pigeonwood	0.1	0.1	0.2	0	0.1
mahoe	0.1	0.1	0	0	0.1
Uncinia spp	0.4	0	0	0	0.1

5.5.4 Plant Preferences

Preference index scores are shown in Table 5.6. The four species with the highest average PI. scores were wineberry, pohuehue, fuchsia and lawyer. wineberry was prefered in all months with scores ranging from 0.75 in November to 0.95 in May.

Pohuehue's PI score of 0.96 in November was the highest of any species in any month. In fact the only month Pohuehue was not highly preferred was in August when it scored -0.65. Fuchsia was a highly sought after food item in November and February but had scores of -1.0 in May and August. Winter leaf-fall significantly reduced the availability of pohuehue and eliminated the deciduous fuchsia as a food sources for possums over autumn and winter months (pers obvs). As a consequence the negative scores reflect non-availability rather than a major shift in preference for either species.

In February and May PI. scores for lawyer were close to neutral (0.08 & 0.07, Table 5.6). In August the score was 0.58 and in November the PI. was 0.91.

Coprosma spp were an important understorey component (Table 5.5). In May, August and November their availability was greater than their contribution to possum diet and preference was negative. In February preference was close to neutral (Table 4.6.).

Mahoe leaves were a highly preferred food source in August (PI. 0.91, Table 5.6) and pate was a preferred food in May (PI. 0.59, Table 5.6). Both species had negative preference indices for all other months.

Although never a large component of possum diet (see Table 4.2) mistletoe was a preferred food item in November with a PI. score of 0.70. In February its

score was close to neutral (0.02) and during May and August its PI was negative. With a % availability score of 0.25 mistletoe was one of the rarest 'preferred' species and although its contribution to diet was small when averaged over four months it was still approximately twice as common in possum stomachs as it was in the forest.

Plants present in significant amounts but generally avoided include silverbeech, horopito, broadleaf, tree ferns, miro, putaputaweta and bryophytes

In summary, four species (wineberry, pohuehue, fuchsia and lawyer) are highly preferred whenever available, a variety of other plants including mistletoe, ferns, rohutu, kaikomako, kamahi mahoe and grass are preferred but only at certain times of the year.

Preference indices were not calculated for fruit or invertebrates both of which were consumed by possums. The availability of fruit and insect larvae varied seasonally neither, was abundant in November when vegetation sampling took place. Moreover obtaining estimates of fruit and in particular insect biomass comparable with those gained for vegetation is an inherently difficult task.

5.5.5 Kill rates

The average kill rate at poison baits set along the Baker Creek line was 0.135 possums/bait/night. Kills along the Moa Creek line averaged 0.105 possums/bait/night. The mean kill rate over both lines.was 0.12 possums/bait/night.

Table 5.6 Seasonal P.I. scores for plant species/groups sampled in vegetation survey. (** denotes deciduous, * semideciduous).

Species	FEB PI	MAY PI	AUG PI	NOV PI	AVG PI
wineberry	0.88	0.88	0.88	0.69	0.83
poehuehue*	0.93	0.86	-0.64	0.95	0.52
lawyer	0.14	0.14	0.62	0.92	0.45
grass spp.	0.47	0.83	0.91	-1	0.3
Pseudopanax spp	-0.38	0.37	0.6	-0.63	-0.04
fuchsia**	0.86	-1	-1	0.89	-0.06
kamahi	-0.61	0.54	0.52	-1	-0.14
pirita	0.01	-1	-0.35	0.69	-0.14
Myrsine divaricata	-1	0.5	-1	-1	-0.3
Asplenium spp	-0.74	-0.49	-1	0.66	-0.39
rohutu	-1	0.46	-0.19	-0.87	-0.4
pate	-1	0.56	-0.34	-1	-0.44
shield fern	-0.38	-0.39	-0.24	-0.78	-0.45
mahoe	-1	-1	0.93	-1	-0.52
kaikomoko	-1	0.78	-1	-1	-0.55
Blechnum spp	-1	-1	-1	0.71	-0.57
Coprosma spp	-0.12	-0.74	-0.53	-0.94	-0.58
herb spp.	-1	-0.8	-1	-0.04	-0.71
ferns	-0.46	-1	-0.86	-0.91	-0.81
bryophytes	-0.83	-0.91	-0.83	-1	-0.89
ribbonwood	-1	-1	-0.55	-1	-0.89
silver beech	-0.99	-0.88	-0.91	-0.97	-0.94
broadleaf	-1	-0.91	-1	-1	-0.98
putaputaweta	-1	-1	-1	-1	-1
Cyathea smithii	-1	-1	-1	-1	-1
kahikatea	-1	-1	-1	-1	-1
Dicksonia squarrosa	-1	-1	-1	-1	-1
pigeonwood	-1	-1	-1	-1	-1
horopito	-1	-1	-1	-1	-1
Uncinia spp	-1	-1	-1	-1	-1
Parsonsia capsularis	-1	-1	-1	-1	-1
Halls totara	-1	-1	-1	-1	-1

5.6. Discussion

5.6.1 Diet patterns

Selective feeding

Almost wherever possum diet has been studied a common feeding pattern has emerged. Typically a wide range of species are ingested but relatively few provide the bulk of diet (Green, 1984). Leathwick, *et al.* (1983) studied the diet of possums in Pureora Forest and found that kamahi, tawa and raukawa (*Pseudopanax edgeleyi*) dominated diet. In Australia, Freeland and Winter (1975) observed that 66% of possum feeding time was spent browsing mature *Eucalyptus* leaves. Fitzgerald (1976) showed that kamahi and northern rata contributed over 60% of annual diet in the Orongorongo valley, and Coleman, et al. (1985) found that kamahi and southern rata contributed similar proportions to the diet of possums in central Westland. In this study the general pattern is repeated with possums showing strong preferences for a few key food items (wineberry, pohuehue etc.).

Seral species in the diet

Preference indices show foliage is not eaten at random and certain species are highly favoured. It is perhaps signifigant in terms of diet selection that the four most preferred plants, wineberry, pohuehue, lawyer, and fuchsia are all seral species.

When the foliage of seral plants was available, Haast Valley possums readily adapted their feeding behaviour to make the best use of the resource. The switch in diet to exploit the spring growth in pohuehue and fuchsia is a good illustration. The signifigant increase in the consumption of pohuehue and fuchsia which occured between August and November was associated with a

flush of new shoots and expanding leaves. Most of the pohuehue and fuchsia material found in November stomach samples consisted of these young shoots and leaves. In the Haast possum population another seral species, wineberry, contributed the greatest amount to diet.

Procter-Gray (1984) studying the feeding behaviour of brushtailed possums in North Queensland rainforest found colonising and introduced ('weed') plant species formed a high proportion of possum diet. In New Zealand seral species such as wineberry, fuchsia, and mahoe have been commonly recorded as preferred species (Green, 1984). Although the reasons for an animals' selection of food are notoriously complex it seems likely that some species have nutritional properties which make them an attractive Opler (1978) observes that early seral stages are often dominated by decidous/semi-decidous species and succeeding stages characterised by trees with longer periods of leaf persistence. Fuchsia is one of New Zealands few decidous trees, and pohuehue, wineberry and lawyer all have relatively short lived leaves (Wardle, 1978). Although there are relatively few decidous species in the New Zealand indigenous flora they are most strongly represented in the seral communities. Opler (1978) suggests a relationship between increased chemical defence and increased leaf persistence and Cates and Orians (1975) have shown that the relative degree of palatability decreases with the succession status of the species. The palatability of seral species to herbivores may relate to a tendency in plants to devote fewer resources to the making and storing of defensive compounds in leaves if those leaves are short lived (Cates and Orians,.1975).

Although possums relied heavily on a leaf diet, their food resources were not constant through the year. Their feeding patterns were strongly influenced by seasonal shifts in availability and perhaps palatability of key food items.

Possums in the study area seemed equally adept at compensating for seasonal shortages in some important foods. During May and August leaves of preferred species were less plentiful than in the warmer months. Fuchsia had lost its leaves, little fruit was available and there was a steady decline in the amount of foliage retained by pohuehue and wineberry. The feeding behaviours possums appeared to adapt in response to this situation were to widen the scope of their foraging and ingest a greater variety of food items in May (Figure. 4.3b). They exhibited flexibility in foraging behaviour, utilising less preferred species which had retained there leaves such as rohutu, pseudopanax, kaikomako and kamahi and spending more time ground feeding as indicated by the grass and larvae consumption which occured in May and August. (Table 5.2).

The importance of invertebrates as a food source in this study contrasts with the results of possum diet studies in other indigenous forests. Previous studies have recorded the presence of invertebrates (see Cowan & Moeed, 1987, for references) but only as a relatively small component of diet. Cowan and Moeed (1987) made a specific study of invertebrates in possum diet in broadleaf-podocarp forest. They found that although invertebrates were frequently eaten their contribution to total food intake was small (invertebrates never contributed more than 3% of the wet weight of stomach contents). The only New Zealand studies which have recorded signifigant proportions of invertebrates in possum diet were both in exotic plantations (Clout, 1977 and Warburton, 1978). The proportions and seasonal patterns of invertebrate consumption that Clout (1977) recorded are similar to those in this study, 30 out of 31 stomachs collected in September contained Dipteran (bibonid) larvae, with an average of 336 larvae per stomach. Maximum occurence of larvae was 26% of the dry weight of stomach contents. Both Warburton (1978) and Clout (1977) suggested that possums actively sought out and ate these larvae. Given

their consumption levels it seems reasonable to assume that larvae were being actively sought by possums in the Haast Valley. McColl (1975) and Moeed and Meads (1985) reported sharp increases in the abudance of dipteran larvae inhabiting leaf litter in winter months. Therefore it also seems likely that the maximum period of larvae intake coincided with the maximum period of larval abundance.

Fruit contributed 9.6% of summer diet and like larvae was readily taken as a supplement to a staple leaf diet. Fruit material is generally more digestable than leaves and provides a greater intake of energy per unit time.(Williams, 1982; Ward). It has been commonly recorded in the diet of possums (eg. Fitzgerald,1976; Coleman et al. 1985; Cowan, 1990). Cowan (1990) found possums ate fleshy fruits of almost all species when available in broadleaf-podocarp forest. It was also observed that the partial replacement of leaves in the diet by fruit was associated with the build up of body fat reserves in late summer and autumn. Similar changes in animal condition were observed in Haast possums.

Fitzgerald (1978) suggests that the sheer bulk of leaves required to provide adequate nutrition, or the inadequate nutritional constituents in leaves, may necessitate the ingestion of some supplementary food. It is not possible to tell if the intake of insect larvae in late winter and fruit in late summer are examples of this phenomena or merely opportunistic exploitation of two seasonally abundant resources

5.6.2 Competition with native birds

Previous studies (eg.Mills & Mark 1977) have demonstrated that some introduced mammals and native birds share similar food preferences. Leathwick et al. (1983) implicated browsing mammals and in particular the

possum, as a contributing factor in the demise of the North Island kokako. Working in South Westland forests Rose et al. (1990) recorded that kaka numbers declined markedly with increasing possum density/history of occupation. A study by O'Donnell and Dilks (1986) on the ecology of forest birds in South Westland highlighted the importance of plant species which, although form only a small element of the forest structure, are critical for the maintenance of bird populations. Examples include the use of mistletoe flowers by kaka, fuchsia flowers and fruit by bellbirds and tuis, and the reliance of pigeons on Pseudopanax fruit and the buds and leaves of pohuehue.

Analysis of possum diet in this study has shown that many of the species important to birds in South Westland are also preferred possum foods. If browsing pressure increases it may critically restrict the food supply of some bird populations. As Rose *et al.* (1990) have already shown in other areas of South Westland this competition for food is likely to have its greatest impact on specialist feeders such as the kaka.

Possums consumed large quantities of larvae over the winter period, some stomachs containing several hundred larvae. Many bird species living in these forests (eg. yellow breasted tit, rifleman, brown creeper, and are almost entirely insectivorous) (Wardle, 1984). Although speculative, it is possible that a dietary overlap exists between birds such as tits who feed in leaf litter and possums, especially as larvae are eaten at a time of the year when other food sources for insectivorous in short supply.

5.6.3 Possum densities and there impacts on preferred species.

Population density

No direct measure of population density was made in this study. However by

comparing the kill rates from Haast poison lines with those recored in other areas a useful indication of possum densities can be gained. Clout & Gaze (1984) studied possum populations in beech forest in Nelson Lakes National Park. During their study baits were set along an altitude transect at 50 m intervals . In areas with kill rates of 0.16/bait/night it was later calculated that possum density was 0.33/ha At higher altitudes kill rates were 0.08 possums/bait/night and population densities were calculated to be 0.26 possums/ha. The kill rate of 0.12 possums/bait/night at Pleasant Flat seems to indicate that possum densities are at similar levels. However, the close bait spacings used in this study (10-15 mc.f. 50 m Clout & Gaze 1984) probably cause an underestimate of Haast populations when direct comparisons are made. The close bait settings used in this study maximised the number of animals killed in the area, but probably meant fewer animals were killed per bait than would have been the case if wider spacings had been used. It seems likely therefore that densities are at the level of 0.5-1.0 possums/ha within the study area.

From a national perspective the density of possums in the Haast Valley is low. Post peak populations in North Island Podocarp-broadleaf forest were estimated at 8.5 possums/ha (Crawley, 1973). Coleman et al (1980) recorded possum densities of 25.4/ha in Westland Podocarp-broadleaf forest adjacent to pasture, in mid-altitude Rata-kamahi associations densities were around 7.0/ha and as low as 1.9/ha in higher altitude.

Pleasant Flat possum densities relative to other areas of the Haast Valley.

The vegetation, geography and history of possum occupation of the Pleasant Flat area all suggest that it supports possum densities atleast as high as any other site in the Haast Valley. When a catchment is being colonised by possums, valley flats are often a main invasion route. Fraser (1992) recorded

that a colonising possum population in the Arawata Valley had a clear altitudinal distribution. Densities were markedly higher on the forested valley flats and lower slopes than those occuring at higher altritudes. Such distribution patterns seem even more likely along the Haast valley given ease the of access to valley flats provided by the Makarora-Haast highway.

The vegetation in the study area lies just within the altitudinal limits of the mixed beech-podocarp forest described by Mark (1977). As such they are the first stands of relatively diverse beech forest possums colonising from the Haast Pass encounter. Forests lower in the valley and to the west are similarily diverse but have a shorter history of possum occupancy.

Possum impacts in beech compared to other forest types

In the literature there are occasional reports on the impacts of possums in beech forest (Grant, 1956; James & Wallis, 1969; James, 1974). However, most studies of possum populations and changes enduced in vegetation have been concentrated in other forest types eg. (Fitzgerald, 1976; Leathwick et al.,1983; Pekelhering and Batchelor, 1983).

Preferred species form an important structural component of podocarp/broadleaf and rata/kamahi forests. High numbers of possums in these more complex forest types have resulted in widespread and progressive mortality over the last 40 years (Wardle, 1974; Pekelhering & Reynolds, 1983; Leutert, 1988). In the Podocarp-broadleaf forest of the southern North Island palatable components of the sub-canopy and canopy have been selectively browsed (Fitzgerald, 1976). This browsing has not only reduced the proportions of preferred species but resulting increases in canopy gaps have increased the incidence of light reaching lower tiers further altering forest composition by favouring the regeneration of light demanding species over slower growing

shade tolerant ones (Brockie, 1992).

Possum related damage to beech forest is less obvious. Beech leaves are not a preferred food and where populations have become established possums seem to have had little direct affect on tree health or forest structure. However the fact that beech is the dominant canopy tree does not imply that it makes up the forest ecosystem in its entirety. Many of the plants recorded as important food species in other indigenous forests are also components of beech forest, especially at lower altitudes and in wetter areas (Wardle,1984). Seral communities, sub-canopy species, and rarer plants such as mistletoe are all vulnerable despite the unpalatable canopy.

Until now, the relationship between possum diet and vegetation has not been studied in detail in beech forest. A contrast between the results of this study and others carried out in more complex forest types is the relative proportion that the highly preferred food species contribute to forest biomass. In the mixed podocarp stands of Pureora Forest the four most important species contributed over 32% of the vegetation. In Mapara forest they made up over 50% of available vegetation (Leathwick et al, 1983) In the Orongorongo valley where possums had been present for over 75 years the four main food species still contributed 24% of vegetation cover (Fitzgerald, 1976). In this study it is estimated that pohuehue, wineberry, fuchsia, and lawyer, the four main food plants, together make up only about 5% of foliage biomass.

An important point is that although palatable species may form a small proportion of biomass they may make an invaluable contribution to species diversity. In the Pleasant Flat forests 16 out of 22 plant species/groups found in the sub-canopy were recorded as preferred foods in this or previous studies. By selectively browsing particular species such as wineberry and fuchsia, possums may reduce diversity and accentuate the heavy bias towards unpalatable

biomass which already exists in a beech forest ecosystem.

Possums living in beech forest concentrate there feeding efforts on a small proportion of the vegetation, so an eventual reduction in or elimination of preferred species seems inevitable once possum populations become established. Before such predictions can be made, however, two important variables must be considered

1. Possum density
2. The regenerative capacity of browsed species

A relationship between possum density and palatable biomass

Within New Zealand habitats a strong relationship exists between possum density and total food biomass/ha (Green, 1984) The obvious implication of this is that the palatable component in beech forest has to support far fewer animals than do preferred species in more complex forests. In fact when different forest types are compared the ratios of palatable biomass to possum density are broadly similar between areas. Thus the actual browsing pressure on preferred species in beech forest may be similar to that which occurs in mixed podocarp or rata-kamahi associations even though beech forests support far fewer possums/ha.

The regenerative capacity of preferred plants

Knowledge of population density and potential browsing pressure is of little use in predicting the impacts of possums unless there is some understanding of the ecology and regenerative capacity of browsed species. For example, the liane, pohuehue, probably sustained the most intense browsing pressure of any species surveyed in the Pleasant Flat forests. And yet its rapid growing habit will probably ensure that it is not eliminated from these stands. The ability of

other species such as fuchsia to cope with possum browse in these forests is less certain. The carbon balance, critical to the continued functioning of any plant, is regulated by the ratio of photosynthetic: non photosynthetic tissue (Payton, 1983). This balance is far less robust in a woody species like fuchsia than it is in plants such as pohuehue and lawyer. That individual plants are typically selected and continually browsed (Green, 1984) increases the likelihood of eventual death. Coleman and Pekelhering (in prep) recorded a rapid elimination of fuchsia from forests on Stewart Island with moderate (4-5/ha) but slowly rising possum densities. In South Westland the health of these seral forests is related to the length of possum occupation (Rose et al. 1990)

Mistletoe in possum diet

Results indicate that mistletoe was a very minor component of possum diet. It formed only 0.5 % of annual diet and never contributed more than 1.4 % in any sampling month. Its comparable scarcity in the forest means that it is quite highly ranked in the list of preferred species (P.I scores). There is however a large gap between its preference rating and those of the top two or three food species.

Before the role of mistletoe in possum diet can be conclusively stated it would be prudent to collect data from larger samples and/or take samples over a longer time frame than was posible in this study . These recommendations are made for two reasons:

1) Mistletoe plants form a tiny proportion of forest biomass. The little mistletoe foliage present occurs as dense discrete packages often situated high in the beech canopy. Given the possums' reliance on plants growing in the shrub and sub-canopy tier it seems probable that only a small proportion of possums in any population will come into contact with a plant on any feeding

night. If a low proportion of animals are feeding on mistletoe there is a likelihood that small sample of possum stomachs (for example, in this study) will not contain mistletoe.

2) Mistletoe plants may not be uniformily palatable to possums from year to year. In the Haast Valley few flowers or fruit were seen on mistletoe plants over the 1990/91 season (pers. obsv.) and this may have affected mistletoes attractiveness as a food source for possums The results of this study and others (eg. Cowan,1990) have shown possums avidly consume the flowers and fruit of native trees .Unfortunately only by sampling over a longer time period would it be possible to determine if possum browsing fluctuates in response to variation in mistletoe flower and fruit production.

5.7 Conclusions

Possums utilised a wide range of different food types but at any particular time of the year diet was dominated by two or three food species. The four main food plants, pohuehue, wineberry, fuchsia, and lawyer, contributed around 5% of foliage cover, but provided 65.3 % of possum diet. This selective feeding pressure may alter the abundances of preferred species over time, especially if possum densities rise further accentuating the bias towards "unpalatable" biomass which already exists in beech forest ecosystems.

Mistletoe was not an important food item, contributing less than 1% of annual possum diet. Its comparative scarcity in the forest however gives it a relatively high ranking amongst preference indices scores.

CHAPTER SIX

Conclusions on the present and possible future impact of possums on mistletoe in the Hasst Valley.

A study by Wilson (1984), and anecdotal reports of plants disappearing from North Island forests suggest that mistletoes are vulnerable to possum predation. Data from tagged plants in this study confirms that possums are browsing mistletoe in the Upper Haast Valley. However the proportion of plants attacked and the severity of these attacks appears lower than that reported by Wilson (1984). The relatively low impact of possums on monitored plants is supported by the evidence of very little mistletoe being consumed as part of possum diet.

Possums have been present in the Upper Haast area for at least 30 years, and present possum densities around Pleasant Flat are likely to be as high as any other site in the Haast Valley. Despite this possum presence mistletoe is still common in forests around the study area (at least as common as in comparable "possum free" sites in the Thomas Valley). This suggests that as yet possums have not had a significant effect on mistletoe populations in the area.

It seems reasonable to assume that for the mistletoe population to have maintained itself at its present "high" densities, browsing pressure has remained at or below its present level since the time of possum colonisation. Whether browsing pressure is on the increase is an interesting question but unfortunately cannot be answered from a 12 month study. What has been

determined is:

1) A small but significant proportion of mistletoe plants are being browsed

2) Possum browsed plants are less healthy than unbrowsed mistletoe plants

Only through continued monitoring will it be possible to know if browsing pressure is mounting, and if so what the long term consequences of this browsing will be. Wilson, (1984) noted that repeated mistletoe plants repeatedly reduced in size by possum browsing produced fewer flowers and fruits than unbrowsed plants. If further monitoring revealed that plants currently under attack are dying out or suffering an inhibited reproductive performance, then a reduction in the number of mistletoe inhabiting these forests will be the outcome The historical coexistence of possums and mistletoe on the site for nearly thirty years suggests that this process has not yet begun or if occurring is a gradual one.

It is possible the mistletoe-possum relationship contains some threshold at which point a period of apparent stasis rapidly alters. This threshold might involve the unbalancing of mistletoes required ratio of photosynthetic : non-photosynthetic plant tissue, or perhaps a switch in possum feeding behaviour producing a rapid increase in browsing pressure For example, if ungulate browsing pressure were to increase on seral plant species (presently important in possum diet) possums might respond by increasing their intake of minor dietary species like mistletoe. Possums in other areas of New Zealand have readily switched diets in response to changing availability of food species (Green, 1984). Although speculative such scenarios could result in a dramatic decline of the mistletoe population.

Management implications

What future mistletoe has in the Haast Valley and South Westland has yet to be determined. The forested valley floor between the Landsborough and Burke confluences may well be the testing ground on which the question of mistletoe survival in South Westland is first answered. If mistletoe continues to coexist with high possum numbers then perhaps the rationale for control in other areas if based solely on mistletoe conservation could be reviewed. If negative change occurs, and is monitored then solid evidence as to the benefits of sustained possum control are gained. At present much of the rationale for "pest " control is based upon circumstantial rather than hard evidence. If such evidence is gained control should be carried out, if not at Pleasant Flat then there must be a continuation of control in areas of SouthWestland where possums have not yet reached high numbers. Commendably DOC are monitoring the condition of mistletoe in their operational areas. However, there is perhaps as much, if not more information, to be gained on the benefits (or otherwise) of possum control by monitoring a comparable mistletoe population in an area supporting high possum numbers. Pleasant Flat is such an area.

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Appendix A Leaf area changes of individual mistletoe plants at Pleasant Flat (* denotes flower buds present in November 1991).

UNBROWSED

Plant no.	% Leaf area lossed	% Leaf area replaced	% Net Change
PF 2	-100.00	0.00	-100.00
PF 3	-42.39	78.45	36.06
PF 4*	-35.28	41.19	5.91
PF 5	-20.66	127.81	107.15
PF 6	-34.77	122.77	88.00
PF 7	-24.04	64.05	40.01
PF 8	-53.20	94.49	41.29
PF 9	-90.13	8.53	-81.60
PF 10	-57.72	135.93	78.21
PF 11	-48.61	59.56	10.95
PF 12	-45.80	61.56	15.76
PF13*	-16.45	46.35	29.90
PF14*	-65.22	88.59	23.37
PF 15	-64.50	142.21	77.71
PF 16	-83.08	61.11	-21.97
PF 17*	-39.02	45.86	6.84
PF 19	-45.62	47.07	1.45
PF 20	-59.82	70.80	10.98
mean	-51.46	72.02	20.56

BROWSED

Plant no.	% Leaf area lossed	% Leaf area replaced	% Net Change
PF 1	-86.09	68.80	-17.29
PF 18*	-73.05	70.09	-2.96
mean	-79.57	69.45	-10.13

Appendix B Leaf area changes of individual mistletoe plants at Deer Stalkers Flat (* denotes flower buds present in November 1991).

UNBROWSED

Plant no.	% L. A. lost	% L.A. replaced	Net Change (%)
DS 2	-37.63	88.02	50.39
DS 5*	-100.00	25.58	-74.42
DS 6*	-87.55	19.43	-68.12
DS 7	-60.27	120.33	60.06
DS 8*	-65.42	40.60	-24.82
DS 9	-26.08	94.16	68.08
DS 10	-66.94	91.97	25.03
DS 11	-21.40	129.95	108.55
DS 12*	-40.82	101.07	60.25
DS 13*	-30.63	48.75	18.12
DS 14*	-48.22	145.26	97.04
DS 15*	-31.12	67.52	36.40
DS 16	-43.12	136.56	93.44
DS 19	-36.09	152.56	116.47
DS 20	-8.99	77.69	68.70
mean	-46.95	89.30	42.35

BROWSED

Plant no.	% L. A. lost	% L.A. replaced	Net Change (%)
DS 1	-65.24	56.46	-8.78
DS 3	-70.17	93.31	23.14
DS 4	-93.05	28.77	-64.28
DS 17*	-35.56	56.24	20.68
DS 18*	-90.88	84.40	-6.48
mean	-70.98	63.84	-7.14